The Impact of Designing Transdisciplinary STEAM Curriculum Using Authentic Assessment on Transforming Students Learning: A Case Study in UAE

أثر تصميم مناهج ستيم المتعددة التخصصات باستخدام تقييم أصيل على تحويل تعلم الطلاب: دراسة حالة في الإمارات العربية المتحدة

by

AREEJ ELSAYARY

A thesis submitted in fulfilment

of the requirements for the degree of

DOCTOR OF PHILOSOPHY IN EDUCATION

at

The British University in Dubai

Prof. Sufian Forawi

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Abstract

STEAM education is one of the new reforms in science education that promotes students' scientific, cognitive, social and psychomotor skills. The alignment of a transdisciplinary STEAM curriculum with authentic assessment has a positive impact on transforming students' learning as it cuts across the three types of learning: emancipatory, communicative and instrumental learning, that were used as a conceptual framework to guide this study. The main purpose of the study was to investigate the impact of designing a transdisciplinary STEAM curriculum using authentic assessment on transforming students' learning in a vocational institute in UAE. A multiphase mixed method design has been used in this study, in two phases. A document analysis of the lesson plans and curriculum developers' and teachers' questionnaire were administered in the first phase. The participants were two groups of 21 curriculum developers and 30 teachers in science, technology, engineering, language art, design art, and mathematics. A quasi experiment "pretest posttest control group" using a closed-ended survey was followed by focus group questions that were administered in the second phase of the study. Participants in this phase were 80 students from grade 12 (40 in control groups and 40 in experimental groups). The treatment of the experimental groups was the link between aligning the transdisciplinary STEAM curriculum and authentic assessment, where students were exposed to the three types of learning: emancipatory, communicative and instrumental learning.

The results revealed that the design of the transdisciplinary STEAM curriculum using authentic assessment had a positive impact on transforming students' learning, where a change in their frames of reference (transformation of perspectives and habits of mind) occurred. The use of authentic assessment tasks allowed students to have several checkpoints to reflect, receive feedback and self-assess their work. There was a significant difference between the pretest and posttest where the combination of the three types of learning helped in transforming students' learning. The results of the study emphasize the importance that exposing students to the three types of learning while solving complex real-world problems collaboratively and self-assessing their learning has on transforming the students' frames of reference. Strong correlations were found between emancipatory, communicative, and instrumental learning, and students' results. Furthermore, adding art to STEM subjects allowed students to reach the highest level of creativity where they were shifting between divergent and convergent thinking.

Keywords: Transdisciplinary curriculum, STEAM, authentic assessment, transformative learning, emancipatory learning, communicative learning, instrumental learning.

ملخص

يعتبر تعليم ستيم (العلوم، والتقنية، والهندسة، واللغة، والفنون، والرياضيات) هو أحد الإصلاحات الجديدة في مجال التربية العلمية التي تعزز مهارات الطلاب العلمية والإدراكية، والاجتماعية والحركية. كان لمحاذاة منهاج ستيم والتقييم الأصلي تأثير إيجابي على تحويل تعلم الطلاب لأنه يمر عبر ثلاثة أنواع من التعلم: التعلم التأملي والتواصلي والحركي وتعتبر هذه الأنواع الثلاثة هي الإطار الفكري الذي تم إتباعه في هذه الدراسة. كان الهدف الرئيسي من هذه الدراسة هو قياس تأثير تصميم منهاج ستيم المتعدد التخصصات باستخدام التقييم الأصيل على تحويل تعلم الطلاب. وقد استخدم تصميم متعدد المراحل ومختلط في هذه الدراسة باستخدام مرحلتين. وتم في المرحلة الأولي إجراء تحليل لوثائق خطط الدروس واستبيان لمطوري المناهج الدراسية والمعلمين. كان المشاركون مجموعتين: 21 من مطوري المناهج الدراسية و30 معلما في مجالات العلوم والتكنولوجيا، والهندسة، واللغة، والفنون، والرياضيات. أما المرحلة الثانية تم عمل تصميم شبه تجريبي لمراحل ما قبل وما بعد الاختبار من خلال استبيان للطلاب يتبعها أسئلة لمجموعة التجربة. كان المشاركون 80 طالبا من الصف الثاني عشر (40 من المجموعة الاولى و40 من المجموعة التجريبية). كانت التجربة هي الرابط بين مواءمة المنهاج ستيم المتعدد التخصصات والتقييم الأصيل حيث تعرض الطلاب لأنماط التعلم الثلاثة: التعلم التأملي والتواصلي.

وأظهرت نتائج الدراسة بأن تصميم المنهج ستيم المتعدد التخصصات باستخدام التقييم الأصيل له أثرا إيجابيا على تحويل تعلم الطلاب حيث حدث تغيير في إطار مراجعهم (تحول وجهات النظر وطباع العقل). وجود التقييمات الأصيلة سمح للطلاب المرور بعدة نقاط للتدقيق والتغذية الراجعة، وإجراء التقييم الذاتي لعملهم. وجد فرق كبير بين ما قبل وما بعد التجربة والتي ساعد فيها الأنواع الثلاثة من التعلم في تحويل تعلم الطلاب. أكدت نتائج الدراسة على أهمية تعريض الطلاب إلى الثلاثة أنواع من التعلم وإجراء تقييم أصلي وذاتي لتعلمهم مما له أثر في تحويل إطار مراجع الطلاب من خلال حل المشاكل المعقدة في العالم الواقعي. تم العثور على ارتباطات قوية بين التعلم التأملي والتواصلي والحركي في التأثير الإيجابي على نتائج الطلاب. علاوة على ذلك، فإن إضافة الفنون إلى مواد ستيم يسمح للطلاب بالوصول إلى أعلى مستوى من الإبداع حيث يتحول الطلاب بين التفكير المتباعد والمتقارب.

الكلمات والعبارات الرئيسية: منهج متعدد التخصصات، نظام STEAM، التقييم الأصيل، التعلم التحويلي، التعلم التأملي، التعلم التواصلي، التعلم الحركي.

DEDICATION

The completion of my dissertation is one of the most challenges that I had to face. This couldn't be possible without the support of my family and friends. I dedicate my dissertation work to my family and friends. My parents' words of encouragement and their push for tenacity that still ring in my ears.

A special feeling of gratitude is to my husband Kareem who supported me and inspired me that I can do the best in my life. I dedicate this work and give special thanks to my lovely kids Jumana, Yaseen, and Yousuf for always making me smile and for understanding of those times I took to complete my study instead of spending time with them. I also dedicate this work to my best friends and colleagues who supported me with their words during the years of my study.

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Chapter One: Introduction

1.1 Introduction

There is a great need to focus on transformational learning for workers in competitive economies, to lead to a knowledge-based economy through a reformed curriculum and assessment in schools and higher education (Howes et al., 2013; Millar, 2011). As a result, this will lead the focus from teaching to students' learning where they are engaged in student centered environment. This needs the focus to be on transforming students' learning by constructing their frames of reference and changing their habits of mind through critical reflection, rational discourse, and transformation of perspective. It is a process of questioning beliefs, values, and perspectives that form a personal frame of reference (Lange, 2015).

It is important not to ignore the importance of designing transdisciplinary curricula using authentic assessment tasks as learning, that lead to successful transformational learning (Naidoo & Kirch, 2016; Turner, 2015). Transdisciplinary curriculum is an integrated curriculum that require complex integration between subjects where there is blurry between the subjects' boundaries (Drake & Reid, 2010). Authentic assessments are another form of formative assessment where students perform tasks rather than selecting answers (Lichfield & Dempsey, 2015) such as learning logs, projects, inquiry-based and problem-based tasks that are used also for assessing creativity and possess the characteristic of meaningful learning (Cheng, 2015; Silveira, 2013; Synder, 2013).

Transdisciplinary curriculum (Guzey, Moore & Harwell, 2016) and authentic assessment (Ashford-Rowe, Herrington & Brown, 2014) have common key elements whereby both of them lead to transformational learning. In addition, in designing transdisciplinary curricula using authentic assessment, both are harmonized with the three learning domains (cognitive, affective, and psychomotor domains) that lead to transformative learning (Ashford-Rowe et al., 2014; Guzey et al., 2016). The common key elements are implied in: using motivating and engaging context; the challenging of students; metacognition awareness; transfer of knowledge; reflection and feedback; collaboration; and the use of performance tasks that transfer their learning to new situations (Ashford-Rowe, Herrington & Brown, 2014; Guzey, Moore & Harwell, 2016). Other researchers have stated the importance of the process and the nature of transformative teaching that allow students to be engaged in: critical reflection in an emancipatory learning system to develop critical thinking and self-direction skills; rational discourse in communicative learning to develop communication and collaboration

skills; and centrality of experience in instrumental learning that develops creativity, innovation and problem-solving skills (Merilainen & Piispanen, 2013; Vasquez, Sneider & Comer, 2013).

Curriculum innovation is the implementation of a new curriculum that improves and changes the educational system (Brunderett & Duncan, 2011; Karkkainen, 2012; Law & Li, 2013; Priestly, 2011). The transdisciplinary curriculum is a complex integration between several disciplines in an innovative way (Tan & Leong, 2014). In other words, it is essential for students to use multiple types of knowledge in solving real-life problems, while assessments serve in diagnosing students' abilities and progress toward learning, through several checking points that give them opportunities to reflect (Fook & Sidu, 2013). The innovation in science is the hands-on; technology is in the projects; engineering is the design planning; art is the creative products; and mathematics is in the prominent use of modelling (Drake, 2007; France et al., 2011; Howes et al, 2013). A major initiative around the world especially in UAE (AlSwaleh, 2017) is the movement toward STEM (Science, Technology, Engineering and Mathematics) due to the huge shortage of qualified high-tech workers (Land, 2013). STEM focuses on convergent skills; however, Art focuses on divergent skills (Land, 2013). Accordingly, the shift from STEM to STEAM highlights the change between divergent and convergent thinking that enables students to reach higher levels of creativity (Gettings, 2017). Deloitte (2015) reported that STEM educators should embrace the arts within STEM curricula in order to enhance students' creativity and performance. The arts usually are concerned with expressing, evoking emotions, producing empathic understanding, and imagining new ideas that disrupt habits of minds and open students' minds provoking emotional awareness (Taylor, 2017). In conclusion, the arts enable learners to discover their humanity that aims to educate for sustainability (Taylor, 2017).

On the other hand, there has been focus on the importance of using transdisciplinary STEAM curriculum that lead to transformative learning through the focus of innovative teaching strategies where teachers are the core of the proper implementation (Gettings, 2017; Guzey, Moore & Harwell, 2016; Liao, 2016; Gross, 2016; White & Nitkin, 2014). In addition, there is a great focus on the use of authentic assessment tasks as learning that lead to transformative learning through the continuous use of feedback and reflection during every stage in the learning process (Ashford-Rowe et al., 2014; Cheng, 2015; Fook & Sidhu, 2013; Heddy & Pugh, 2015; Litchfield & Dempsey, 2015; Owen, 2016). Art is considered to drive the STEM learning to transform students' learning (Liao, 2016).

There are different approaches in planning the integrated curriculum, such as Drake's (2007) approach and Beane's (1991) approach. Both approaches suggest different ways of

planning and designing the integrated curriculum where Drake focuses on teachers' collaboration in planning while Beane relies more on teachers co-planning with the students. Leopone (2016) pointed out three main considerations in planning the most integrated curriculum (transdisciplinary) in order to form an authentic learning environment: provide general information to students; serve them; and perceive students as young adults. Regarding the transdisciplinary STEAM curriculum, it is stated that the main assessment concern for the transdisciplinary curriculum is the authentic assessment (Drake & Burns, 2004; Drake & Reid, 2010, 2017; Drake et al., 2016). This is because the authentic assessment requires real-life applications that students are engaged in to perform a task which requires a strong integration between disciplines to solve problems and achieve the end product. However, finding ways of assessing a broad range of knowledge in authentic open-ended tasks is challenging and set as a key to innovate the assessments that promote students' creativity (Foegen et al., 2007; Howes et al., 2013; Kimbell, 2007). Authentic assessment is considered to be assessment as learning that is essential in improving students' learning and teaching strategies (Litchfield & Dempsey, 2015). It has different forms, such as: performance tasks, project-based learning, problem-based learning, e-portfolios, peer and self-assessment (Howes et al., 2013). Designing and implementation of authentic assessments within STEAM curricula shift the focus from teaching to learning in order to form a student-centered environment (Fook & Sidu, 2013). Authentic assessment lies in giving students the practice and experience that allow them to develop the knowledge, skills, and attitudes they need in order to prosper in their careers and in life that lead to a knowledge-based economy (Litchfield & Dempsey, 2015). Authentic assessment requires a complex integration of knowledge where students are involved in real-life scenarios (Drake & Reid, 2010).

Meaningful transformation of students' learning occurs when a focus on developing the learning process is based on their interests, as in the goal of science in society, projects in technology, designing in engineering, creativity in arts, and real problems in mathematics (Howes et al., 2013). The transdisciplinary curriculum is the strongest and most complex integration of knowledge where the boundaries between subjects are blurred (Drake & Burns, 2004). Adding art to STEM is shifting the interconnection from interdisciplinary to transdisciplinary where the strong integration is not only with disciplines but also with the skills and design thinking (Gettings, 2017; Gross, 2016; Liao, 2016). The term "arts" is used for: Design Art, Language, Sociology, Philosophy, Psychology and History (Yakman, 2007). The focus of arts in this research is basically on the Language Art and Design Art. STEM and arts have opposite characters that are completing each other. STEM is objective, logical,

analytical, and reproducible, while arts are subjective, intuitive, sensual, unique, and frivolous (Sousa & Pilecki, 2013). From the neuroscience perspective, the left-brain function requires STEM for the use of analytical thoughts, logic, science, math and language while the right-brain function requires arts for the use of imagination, intuition, holistic thoughts, creativity, art and music (Sousa & Plecki, 2013). Accordingly, the arts in STEM is explained to be the cognitive, physical, and emotional activities that are basics of human experience and necessary for survival (Sousa & Plecki, 2013).

The transdisciplinary design is considered as a curriculum innovation that includes the integrated knowledge, skills and attitudes that are required to be involved in real-world problems, challenging tasks, applications of inquiry and critical thinking (Howes et al., 2013; Zhang & Campbell, 2012). This reform requires teachers to be involved in designing the transdisciplinary curriculum using authentic assessment as a primary assessment that focuses on students' interests, needs, attitudes, and skills (Ashford-Rowe et al., 2014; Beane, 1991; Drake & Burns, 2004; Howes et al., 2013). The curriculum is designed as a planned sequence of learning experiences that includes consideration of planning the aims, intended learning outcomes, contents, teaching and learning strategies, and assessment (McTighe & Reese, 2013). This planned sequence should be aligned in order to ensure successful design of the curriculum. The Understanding by Design (UbD) of McTighe & Reese (2013) provides a planning framework that align curriculum, assessment, and instruction with an emphasis on teaching and assessing for understanding and transforming learning. There is a complementary connection between UbD and STEAM where both are focusing on teaching and assessing for understanding and transfer, and designing curriculum "backward" from those ends (McTighe & Reese, 2013). The UbD is based on seven key principles: it is a way of thinking purposefully about curricular planning; developing and deepening students' understanding; transferring learning through authentic performance tasks; planning the curriculum based on "backward design" by aligning desired outcomes, assessment and learning plans; teachers are coaches and focus on guaranteeing learning, not only teaching; enhance curricular quality and effectiveness through regular reviews of units and curriculum; reflects continuous improvement approach to achievements (McTighe & Reese, 2013). The STEAM is reinforcing and supporting the tenets of the UbD framework for curriculum, instruction and assessment through the utilization of performance tasks and an authentic learning environment (McTighe & Reese, 2013).

Dewey (1933) claimed that aesthetic experience is not only encountered with beautiful objects but also develops from the deepened experience of everyday objects. Transformative learning is based on Dewey's (1933) pragmatic aesthetics and application of learning to the

everyday life and experience of learners where students should be involved in real-life tasks that require integrated disciplines and critical reflection (Parrish, 2009; Pugh & Girod, 2007; Singleton, 2015). Orr (1992) claims that transformative learning requires not only integrated disciplines but also the intellect, emotion and body, where the focus is on the cognitive, affective and psychomotor domains. This is due to many barriers that hinder the use of reflection, including: providing necessary time for reflection where most of the curriculum is calling for breadth rather than depth; and training and preparing teachers to guide students for reflective practices (Singleton, 2015). Reflection is more effective for students when it occurs in collaborative learning where students are interacting together and sharing experiences (Dewey, 1944; Roberts, 2002).

The affective domain refers to the relational knowing where the quality of life is dependent upon relations with healthy environments, communities, and personal connections, in addition to learners' senses and the world beyond (Singleton, 2015). In other words, relational knowing is the awareness of the relationships shared with communities and the natural world (Riley-Taylor, 2004). There are four categories of relational knowing: thinking, feeling, intuition and sensation (Cajete, 1999). As the critical reflection is a cognitive process that is essential for transformative learning, so the needs of emotional investment to engage in self-examination and transformation is another important domain (affective) that should be considered (Singleton, 2015).

The psychomotor domain is the deep engagement of learners who exhibit characteristics of being attracted to their tasks despite obstacles or challenges occurring, they feel joy at completing their tasks (Singleton, 2015). There are four important goals for deep engagement: originality and the need for self-expression; relationships and involvement of others; success and mastery; and curiosity and understanding (Strong, Silver and Robinson, 1995). The Head, Heart and Hand model represented by Orr (1992) sets out an effective pedagogy that brings real life to the curriculum and school environment which requires students to be engaged in authentic tasks and use integrated knowledge that can be transferred to new situations (Pugh & Bergin, 2005; Singleton, 2015). This model implies considering three important domains (cognitive, affective, and psychomotor) in designing the integrated curriculum aligned with authentic tasks. Then, create daily instructional activities that engage students in three types of learning (emancipatory, communicative and instrumental learning) that lead to transformational learning. This will lead the focus to the strong pedagogy that develops students' critical thinking, self-direction, communication, collaboration, creativity and innovation, and problem-solving skills.

1.2 Background of the Research

Countries of the Gulf Cooperation Council (GCC) have seen a global shift toward a knowledge-based economy in the 21st century through moving from the dependence on oil toward the promotion of science, technology, business, tourism and other sectors (Khaleej Times, 2015; UAE Government, 2015; UAE Vision, 2021, 2009). The success of any economy is based on the effective utilization of intangible assets, such as: knowledge, skills, and innovative potential (Hvidt, 2016). Recently, the Gulf leaders emphasized that efforts should be done to diversify their economies and to create jobs with high content knowledge for the population (Hvidt, 2016). This has caused a change in the nature of jobs required in the labour market that lead to a reform in education in order to overcome the disconnect that has occurred between education and the labour market (AlQasmi, 2012). It was stated that there is a need of reformed curriculum and assessment that focus on and shape the learning for work, economy, and future competitiveness that lead to knowledge-based economy (Howes, et al., 2013; Millar, 2011). In order to innovate assessments, there should be ways to assess learning outcomes in authentic open-ended tasks that promote creativity such as: e-portfolios, projects, peer and self-assessment, etc. (Howes et al., 2013; Zhang & Campbell, 2012). In addition, to innovate curriculum design, it is required to use integrated knowledge between subjects to include: real-world problem, challenging tasks, applications of inquiry and critical thinking (Howes et al., 2013: Zhang & Campbell, 2012). As a result, the United Arab Emirates' (UAE) Vision 2021 has stated that investment in science, technology, research and development are the sources that drive the productivity and competitiveness (2009). It became essential to prioritize these areas by investing in graduate programmes that increase students' enrollment in STEM subjects (AlQasmi, 2012). In addition, reforming toward transformation require reform the curriculum into transdisciplinary STEAM to be used as a key to develop 21st century skills to meet the UAE's national strategy goals of transforming to knowledge-based economy (AlSawaleh, 2017).

The World Bank developed the most widely understood way to quantify a knowledge-based economy which is called the knowledge assessment methodology (Hvdit, 2016). Based on that, the World Bank highlighted four pillars of the knowledge economy: economic incentive and institutional regime; adoption of innovation and technology; education and training; and information and communication technology infrastructure. All these pillars are interconnected and considered to be pre-requisites for a successful knowledge economy (Hvidt, 2016). The focus in this study will be on the education and innovation pillars, which are

considered to be the weakest pillars in the Gulf and have some challenges that will be discussed (Hvidt, 2016).

Some of the problems highlighted by the Arab Knowledge Report 2010/2011 are the low levels of research funding; lack of research that focuses on the university level; a lack of emphasis on social science-based research; and a shortage of academic choice (UNDP, 2010). Furthermore, the Arab Knowledge Report 2014 stated that the teaching and the research are not integrated with the cycle of production; and a substantial gap exists between the qualifications and the market demand (UNDP, 2015). Regarding the funding levels, the Arab Knowledge Report 2014 highlighted that the MENA region is well below the world average by 2.13% in using 0.5 percent of its combined GDP on research (R & D) in 2009, while in 2012, UAE used 0.49%, Oman used 0.13%, and Kuwait used only 0.09%. In comparison, Japan used 3.4%, USA used 2.8%, China 1.98%, and Europe 1.96% (UNDP, 2015). In addition, the report stated that the universities in Gulf countries are suffering the consequences from the low level of education in primary and secondary sectors. It has been stated that there should be emphasis on increasing teachers' incentives to perform well and to prioritize quality over the quantity of teaching (World Bank, 2008). Furthermore, the link between the education sector and the job demands is very weak due to the fact that more than 50% of students choose the humanities fields rather than science fields (Hvidt, 2016). Official announcements and policies have been raised in UAE and other Gulf countries that emphasize improvements in the education system, however, this needs time to be achieved (Hvidt, 2016).

A strategic goal of UAE is the expansion of the non-oil sectors in order to enhance the economy that will compete with emerging markets (Ahmed & Alfaki, 2015). Accordingly, a plan to invest around Dh300 billion that includes legislation, technology, education and finance in order to build a vibrant knowledge-based economy has been anticipated. However, the national investment related to this policy exceeded the Dh300 billion, including distribution as the following: Dh128 billion on clean energy projects; Dh72 billion on the renewable energy sector; Dh40 billion in aviation research, development and manufacturing; Dh20 billion on the space sector; Dh31 billion to construct innovation indicators; and Dh6 billion to develop and conduct research centers (Allen & Knibbs, 2015). The budget allocation of education in UAE exceeds 20% of its total government budget and is higher than the benchmark average of 13% (Byat & Sultan, 2014).

Furthermore, the UAE Vision 2021 and the Federal Strategy 2011-2013 highlighted the increase of investment in science and technology and R & D that ensure aligning learning and research outcomes that meet the labor market's demands and produce a knowledge-based

economy (Ahmed & Alfaki, 2015). The minister of education stressed on the fact that UAE is going beyond implementing STEM education to add the art education to be implemented as STEAM (Al Qassemi, 2015). Lancaster (2016) stated that adding art subjects to STEM has started to provide a great focus to reform the curriculum in UAE schools as it will give students motivation, especially for those who tend to study humanities rather than science fields. Accordingly, a shift toward STEM and STEAM education has taken place in UAE where a great number of governmental institutes and colleges have been established (Moonesar et al., 2015). Furthermore, the UAE Science, Technology and Innovation Policy established in November 2015 stated that increasing Emirati participation in the STEM workforce is one of the important pillars that should be considered for the development of a knowledge-based economy (UAE Government, 2015). A particular focus is on developing vocational and technical education and revamping the curricula where the development of critical thinking, creativity and innovation, and problem solving are outcomes of learning (Ahmed & Alfaki, 2015).

Like the Arab Knowledge Report (2014) mentioned above, the report by Jahan et al. (2015) pointed out that universities in Arab countries suffer the consequences from the weak performance of the primary and secondary schools. There is a significant gap between the candidates' qualifications and the labour market demands (Hvidt, 2016). There is very limited emphasis on designing study programmes with a focus on practical labour market skills (Jahan et al., 2015). Accordingly, the lack of demand for actual skills impacts the students' choices of study where more than 50% of students are enrolled in humanistic and business studies and quite few have enrolled in sciences and engineering (Hvidt, 2016). As a result, these factors contribute to weaken the link between the education sector and the labour market (Hvidt, 2016).

Furthermore, enabling students to acquire the competencies needed to be successful citizens is one of the main purposes of the Abu Dhabi Education Council (ADEC, 2015). This is because of the shortage in the UAE STEM workforce where only 21% of students in government universities enrolled in STEM majors (Moonesar et al., 2015). Of the students who enrolled in STEM majors, 31% were studying engineering and 61% were studying natural science; within this, minority were females and majority were males (Moonesar et al., 2015). Accordingly, secondary school curricula in the emirate of Abu Dhabi have been reformed to focus on STEM subjects in 2015 (Moonesar et al., 2015). It has been stated that the biological differences between males and females have little or no influence on their academic ability, including in STEM subjects (UNESCO, 2017). The communicative ideas with females that STEM studies and careers are male domains can negatively affect females' interest,

engagement and achievement in STEM and discourage from pursuing STEM careers (UNESCO, 2017). In addition, influences of female peers is considered to have a significant predictor of females' interest and confidence in scientific subjects (UNESCO, 2017).

In 2012, the UAE ranked 48 out of 65 in mathematics for PISA, while it ranked 44 out of 65 in science (MOE, 2013). In comparison to OECD countries, UAE measured lower than the OECD average by 60 points in mathematics and 89 points below the average in science (MOE, 2013). Accordingly, secondary schools in Abu Dhabi were reformed to increase the focus on STEM subjects (Moonesar, 2015). There is a clear gap between what students learn in the classrooms and the way they are assessed (Drake & Reid, 2017). However, in the classrooms the learning practices don't match the students' assessments, where teachers feel the tension between developing students' creativity and preparing them to perform well in the fact-based assessments (Beghetto, 2015). Students are experiencing the skills of each subject solely when learning separate subjects. However, in the STEAM class, the students experience the essence of the skills of all subjects that are intertwined together in order to produce new and unique ideas. The problem-based learning is considered to be a type of authentic assessment (Howes et al., 2013). Students are engaged in solving ill-structured problems where critical reflection, communication and collaboration, and the challenges and innovations of integrated knowledge in specific content, are integral aspects of learning (El Sayary, Forawi & Mansour, 2015).

Designing a transdisciplinary STEAM curriculum using authentic assessment is considered an innovation in education that raises many questions: how do teachers design this curriculum? Does it lead to increased Emirati participation in the STEAM workforce? What are the changes that occur in students' learning? Does the authentic assessment prepare students to promote themselves in standardized assessments?

1.3 Statement of the Problem

Designing the transdisciplinary STEAM curriculum is essential to ensure successful implementation where students develop their 21st century skills and prepare them for future careers (AlSawaleh, 2017). Many researches have stated the importance of aligning integrated curriculum to authentic assessment that lead to transformative learning (Breunig, 2017; Dake, Reid & Kolohon, 2014; Drake & Reid, 2017; Ghosh, 2017; Greenhill et al., 2018; Naidoo & Kirch, 2016; Turner, 2015; Merilanien & Piispanen, 2013; Vasquez, Sneider & Comer, 2013). However, no researches investigate the alignment between transdisciplinary STEAM curriculum to authentic assessment that lead to transformative learning. Planning a

transdisciplinary STEAM curriculum using authentic assessment as a teaching and learning tool is not an easy task as there are some criteria that should be met: provide real-life context; present complex problems; allow for divergent thinking; require collaboration and communication; promote highly integrated knowledge from different disciplines; allocate time for students' self-assessment and reflection; and drive students' investigation and research (Strimel, 2014).

The English language art is considered to be the language of science and innovation and ultimately the language of the future (AlSawaleh, Mauring, Maboob & Assomull, 2017). The prospective future of the UAE is to focus on the STEAM education through developing a transdisciplinary STEAM ecosystem that includes schools, families, business and community (AlSawaleh, Mauring, Maboob & Assomull, 2017). It was recommended that the early involvement of students' career education should be promoted, where students have the opportunities to explore their potential and choose the career path that satisfies their aspirations (AlSawaleh et al., 2017). Furthermore, students' awareness should be raised about the various opportunities that are available for careers and skills development in the educational sector. Fostering innovation and transforming students' learning can be done through the transdisciplinary approach and the use of authentic assessment tasks within constructivist classrooms (AlSawaleh, et al., 2017).

On the other hand, teaching materials with practical applications where studying and practicing a subject in a real-world context is vastly different (AlSawaleh, et al., 2017). So, preparing students for this learning environment requires innovation in the methodology and curriculum (AlSawaleh et al., 2017). Accordingly, recommendations have been raised that aim to reform the national curriculum into STEAM as a key to develop the skills required to meet the UAE's national strategy goals of transitioning to a knowledge-based economy (AlSawaleh et al., 2017). In addition, there should be a reform of teaching methodologies in order to ensure that teachers provide consistent teaching and use authentic assessment as a teaching strategy (AlSawaleh et al., 2017). Some organizations such as the Organization for Economic Cooperation and Development (OECD), Assessment and Teaching of 21st Century Skills (ATC21S), Partnership for 21st Century Skills (P21), Canada 21 and the International Society for Technological Education (ISTE) are influential participants that advocate for deep learning as an important goal for the 21st century pedagogy (Drake & Reid, 2017).

A study by Saudelli (2014) highlighted the importance of the transdisciplinary curriculum in transforming students' learning in Dubai Women's College. The findings of this study revealed that transformational learning requires in-depth engagement in curriculum

design and implementation in order to successfully connect it to the contextualized learning needs of the learners. The transformative learning theory has been applied and used with adults as it is assumed that children are not able to reflect critically on their learning (Merriam, 2004; Taylor, 2007). However, the transformative learning theory is more effective when it is started with children at a young age as they are capable to reflect on their learning, engaged in learning through their curiosity that motivates them, and become self-regulated of their learning (Singelton, 2015). Accordingly, this study is conducted in an educational institute that focuses on STEM fields with grade twelve students. The STEM education has been a focus of this institute since 2012 and has been developed to STEAM where the language art and design and art were integrated within the curriculum.

Furthermore, UAE set an action plan that states the huge investments of STEM education in schools that will consequently affect the workforce (Mosier, Levine & Perkins, 2013). A significant problem has been introduced which is the tension teachers feel between facilitating transformative learning and the accountability of international assessments that force them to teach toward tests (Heddy & Pugh, 2015). The focus on internal and international assessments reduces the amount of time needed for transformative teaching and learning (Heddy & Pugh, 2015). In addition, assessments set a challenge for teachers where the great focus was on the nature of the integrated knowledge and less focus given to the way students are assessed (Drake & Reid, 2017).

Furthermore, few teachers' education programmes focus on transformative teaching and learning practices, and as a result teacher do not have the skills required to implement such strategies (Heddy & Pugh, 2015). Well educated prospective teachers have great input in impacting and developing the countries in every aspect (Yildirim & Selvi, 2016). Educators carry the responsibility of training prospective teachers as individuals who think scientifically, criticize, communicate, collaborate, accept others, and respect human rights where they will impact students' learning (Yildirim & Selvi, 2016). Development of the STEAM curriculum is like the classic railroad that is switching stations of junctions a hundred times in addition to the mechanical installations that enable railway trains to switch from one track to another (Rolling, 2016). These processes cannot be done without collaboration, where teachers should collaborate in developing the STEAM curriculum rather than individual teachers working in isolation (Rolling, 2016).

1.4 Purpose and Questions

This study is aiming to investigate the impact of designing a transdisciplinary STEAM curriculum and authentic assessment on transforming students' learning in a vocational institute in UAE. The main purpose of the study is fulfilled through two phases.

The first phase of the study is aiming to investigate the perceptions and practices of curriculum developers and authentic assessment. This is considered to be the first part of the main purpose of the study: designing transdisciplinary curriculum using authentic assessment. The first two questions are used to fulfill the first phase of the study.

The second phase of the study is aiming to investigate the cause and effect relationships of aligning transdisciplinary STEAM curriculum to authentic assessment on transforming students' learning. This is considered to be the other part of the main purpose of the study: transforming students' learning. The last two questions are used to fulfill the second phase of the study. The following questions are used to guide this study:

1. How is authentic assessment planned in a transdisciplinary STEAM curriculum?
2. What are the curriculum developers' and teachers' perceptions and practices in designing and planning a transdisciplinary STEAM curriculum?
3. What changes if any, do the emancipatory, communicative, and instrumental learning have on transforming students' learning?
4. How does the students' frame of reference vary after being exposed to the transdisciplinary course and authentic assessment?

1.5 Significance and relevance of the Study

There are three main components that are important to consider in order to transform students' learning: the design of the integrated curriculum; time allocation for authentic assessment; and reflection on every aspect of learning (emancipatory, communicative and instrumental learning) that lead to transformative learning (Naidoo & Kirch, 2016). It was stated in previous researches that the alignment between integrated curriculum and authentic assessment leads to students' transformational learning (Beunig, 2017; Drake, Reid & Kolohon, 2014; Drake & Reid, 2017; Ghosh, 2017; Greenhill et al., 2018; Merilainen & Piispanen, 2013; Naidoo & Kirch, 2016; Turner, 2015; Vasquez, Sneider & Comer, 2013). However, there were no researches who stated the importance of aligning transdisciplinary STEM curriculum to authentic assessment that lead to transformative learning. Accordingly, this study is aiming to investigate the impact of designing transdisciplinary STEAM curriculum using authentic assessment on transforming students' learning. The connection between the

transdisciplinary curriculum and authentic assessment allows teachers to shift the focus from teaching to learning by being facilitators who encourage students to be active learners and construct on their knowledge that they gained earlier (Cross, 1998; Fook & Sidhu, 2013). In other words, teachers were inspired to form a constructivist environment in order to be a "guide on the side not sage on the stage" (Slavin, 2012).

Furthermore, attention to gender dynamics in the classroom and school environment is critical where the qualified teachers can positively influence males' and females' performance and engagement (UNESCO, 2017). Curricular and learning activities have an important role in promoting males' and females' interests (UNESCO, 2017). Assessment processes and tools should not be on gender biased as it may affect females' performances in scientific subjects (UNESCO, 2017). The authentic assessment tasks allow students to explore STEM subjects with the option of using artistic expression that increases females interests toward scientific subjects (Gidcumb, 2016). The use of authentic assessment with the transdisciplinary curriculum requires students to reflect critically on their learning that will cause a change in their perspectives, habits of mind and mindsets which leads to transformation in their learning (Howes et al., 2013). In addition, teachers provide students with constructive feedback about their performance in STEAM courses where they have to revise their perceptions and improve their learning that lead to transformative learning (Gidcumb, 2016). It was stated also that educators should not force students in pursuing careers in STEM fields, they should promote the practices and habits of thinking that are associated with STEAM practices and habits that will serve students and increase their engagement in STEAM fields (Gidcumd, 2017).

Research by Stein et al. (2007) identifies problems that occurred due to the effect of the intended curriculum on the enacted curriculum that addresses many factors, such as: teachers' beliefs and knowledge; orientation of teachers toward the curriculum; classroom structures and norms; and policy contexts. Other studies stated that whenever the system gives well-prepared teachers control over designing assessments, reform occurs easily, and whenever the system limits the assessment methods to teachers the transformation shrinks (Desimone et al., 2005; Labate, 2007). Several studies that focus on designing innovative curricula and assessment to transform learning found resistance in many factors, such as: the assessment methods (Suurtamm et al., 2008); the system management (Marx et al., 2004); and teachers' qualifications (Kidman, 2012). The transdisciplinary curriculum is aligned with the 21st century pedagogies that are being implemented globally (Drake & Savage, 2016; Savage & Drake, 2016). In addition, aligning assessment with the curriculum standards using backward design allows for acquiring deep assessment literacy (Drake & Reid, 2017).

It has been discussed by Prof. Sufian Forawi in "Theoretical Frameworks of Effective STEM Education: The UAE Context" that innovation in methodology and curriculum are important in studying and practicing a subject in a real-world concept which is the incorporation of STEM education into school curricula (AlSawaleh, et al., 2017). However, STEAM is not like STEM: adding the art to STEM allows for the use of a wider variety of habits of mind as well as adding artistic design aesthetics (Getting, 2017). Many artists have seen science, technology, engineering, and mathematics as part of the artistic creative processes (Getting, 2017). DaVinci's studies in anatomy, engineering and art prove the view of artists. Gettings (2017) stated benefits of STEAM that give the students the opportunity to be engaged in a real-life context that integrates different disciplines. Furthermore, it allows students to interchange between divergent and convergent thinking in solving complex problems. Moreover, they are encouraged to use artistic thinking skills and use suitable materials to complete their work. Finally, students observe and reflect on their work and develop understanding and awareness whereby they are able to articulate and demonstrate the use of artistic design (Getting, 2017).

The use of authentic assessments with the transdisciplinary STEAM curriculum enhances students' transformational learning whereby they create projects ideas that are above expectations due to the socio-cultural environment that enhances the communicative learning (Gross, 2016). STEAM highlighted the importance of integrating design thinking as part of the k-12 educational experiences that aim to develop students' creativity, critical thinking, innovation, collaboration, communication and self-direction (Gross, 2016). The design of a transdisciplinary STEAM curriculum should address social and global issues that lead to transformative learning (Liao, 2016). Students use the STEAM curriculum to be engaged in authentic contexts that require them to reflect on their learning, communicate with their peers, and learn from their failures (Gross, 2016). Gross (2016) pointed out the importance of social and cognitive constructivism in designing STEAM that allows students to be engaged in authentic learning tasks in order to transform their learning and change their habits of mind. Liao (2016) emphasized that integrating art into STEM shifts the level of integration from interdisciplinary to transdisciplinary where students should be engaged in authentic assessment tasks such as problem-based learning, portfolios, etc. that lead to transformative learning. Liao (2016) emphasized the importance of emancipatory learning where students should reflect on their learning while engaged in authentic assessment tasks that require a transdisciplinary curriculum.

In order to transform students' learning through a transdisciplinary curriculum aligned with authentic assessment tasks, innovation can be directed toward the creation of new ideas that benefit the society (Turner, 2015). In addition, transdisciplinary STEAM has the potential to address contemporary social issues even on a global scale (Ahn, 2015; Guyotte et al., 2014; Liao, 2016). For both teachers and students, the arts can promote expression, communication, creativity, inspiration, observation, perception, and thinking (Bucheli, Goldberg & Philips, 1991). The presence of the arts within STEM is integral in the development of students' cognitive skills such as listening, thinking about their thinking, problem solving, and decision making (Taylor, 2016). The arts nurture a sense of belonging to a community; foster the sense of being an individual; and open pathways toward understanding people and the cultures that inhabit the world (Taylor, 2016). STEAM education enriches and expands the capacity of STEM education (Taylor, Taylor & Chow, 2013). It is a curriculum philosophy that inspires teachers to be engaged in developing students' 21st century skills (Taylor, 2016). STEAM education provides teachers a space for designing different learning areas through developing a highly integrated curriculum creatively and collaboratively (Taylor, 2016). Finally, STEAM education enhances students' engagement in transformative learning that is based on five interrelated ways of knowing: cultural self-knowing, relational knowing, critical knowing, visionary and ethical knowing, and knowing in action (Taylor, 2016).

1.6 Transformative Teaching and Learning

Transformative teaching is described as increasing students' mastery of key concepts while transforming their learning attitudes, values, beliefs and skills (Slavich & Zimbardo, 2012). It has also been defined by Rosebrough and Leverett (2011, p.16) as "an act of teaching designed to change the learner academically, socially, and spiritually". The point is not only teaching students to acquire knowledge and skills but also to radically transform their approach to thinking and learning (McGonigal, 2005). There are several conditions and processes of learning (emancipatory, communicative, and instrumental learning) that need to be considered and which lead to a paradigm shift (perspective transformation) (Cranton, 2002). As a first stage for teachers before planning for emancipatory, communicative, and instrumental learning, they need to understand their students through an activating event (McGonigal, 2005). The activating event can be anything used to examine students' thinking, and the possible limitations of their understanding, that lies in: understanding students' background, beliefs, and knowledge in order to create an effective critical event; examine students' own perspectives by

providing them with conflicting viewpoints; challenge students' beliefs through creating a disorienting dilemma; and set up a failure-driven approach that motivates them in solving complex problems (McGonigal, 2005). The second stage is to guide students to identify current assumptions by predicting, asking questions, and self-evaluation. In this stage, teachers are responsible for using critical questioning techniques in order to ask students to explain their reasoning and the reasons behind their reasoning. Also, students need to explain their predictions in discussions or as written exercises. The failure-driven approach allows students to communicate verbally and with written work through talking about their thinking while solving problems. Finally, students need to evaluate their work and their peers' work, and provide in-depth reasoning in a small group discussion or as a written assignment (McGonigal, 2005). The third stage is the emancipatory learning plan where students have the opportunity to critically reflect on their work, through: keeping a class journal of questions, observations, and experiences; responding to a specific class experience or reading; and create a perspective history timeline to track changes (McGonigal, 2005). The fourth stage is the social interaction between students in communicative learning which is known as critical discourse by providing them with more extended time of discussions and debates (McGonigal, 2005). The last stage is the instrumental learning where they are engaged in failure-driven exercises of complex tasks and problems as they have the opportunity to observe, interpret events, experiment, use knowledge from different disciplines, and transfer what they have learned into new situations (McGonigal, 2005). On other words, the basic principles of transformational teaching include: facilitating students' acquisition and mastery of key concepts; enhancing their strategies and skills for learning and discovery; and promoting students' positive learning attitudes, values and beliefs (Slavich & Zimbardo, 2012). The core methods used to promote transformational learning are: establishing a shared vision of contents; providing modelling and mastering experiences; challenging and encouraging students; personalizing attention and feedback; creating experiential lessons; and promoting pre-reflection and reflection (Slavich & Zimbardo, 2012).

The transformative learning lies in constructing new knowledge and making meaningful learning that is related to learners' lives (Mezirow, 1997). Students' transformational learning occurs when they change their frame of reference, that includes points of view and habits of mind (Mezirow, 1997). The points of view are easy to change as this occurs through the change in learners' beliefs and attitudes, while the habits of mind are not easy to change as this is the way in which learners think, feel and act in the world and needs learners to be engaged in the process of reflective thinking (Mezirow, 1997). Students solve

complex problems, discuss and reflect on their interpretations, habits of mind and points of view, while instructors are facilitators who facilitate students' learning through engaging them in independent learning involving solving problems, discourse, and critical reflection (Slavich & Zimbardo, 2012). Mezirow (1991) pointed out that transformative learning is a process that allows learners to assess their current perspectives and approaches to life. Learners are then engaged in a dialogue where they communicate together, reflect on their experiences and change their perspectives and approaches.

The process of the transformative learning changes the ordinary learners to extraordinary learners (Ssegawa & Kasule, 2014). Students' frames of reference are shaped by social and cultural influences but are able to be modified when learners solve problems (instrumental learning); discuss problems (communicative learning); and critically reflect on their interpretations, beliefs and habits of mind (emancipatory learning) (Mezirow, 1996). It has been proposed that learners can learn in four different ways, by: elaborating on their existing frame of reference; learning a new frame of reference; transforming habits of mind; and transforming points of view (Mezirow, 2000). The learning environment needed for transformative learning must be appropriate and allow students to be: motivated and self-directed learners; participate, reflect and collaborate on work with their peers; and be empathetic and have professional integrity (Cranton, 1994; Robertson, 1996). Transformative learning develops students' skills to be problem solvers, critical thinkers, and communicators (Ssegawa & Kasule, 2014). In fact, transformational teaching is a process that involves creating a dynamic relationship between learners, instructors and a shared body of knowledge that together promote students' learning and personal growth (Slavich & Zimbardo, 2012). Instructors' roles are viewed to be intellectual coaches who can create dynamic collaboration and communication between learners and instructors in order to master bodies of information (Slavich & Zimbardo, 2012).

Mezirow's focus was usually on the cognitive transformation of learners and lacked the relationship between cognitive transformation and social interactions (Lotz-Sisitka, 2012). Gordon (2014) reflected on the needs for transformative learning and suggested that the form of learning needed should involve "the mediation, cultivation of maturity of how to negotiate, live, and transform a world of contradictions, paradoxes, uncertainty, and unfairness" (p. 91). Lotz-Sisitka et al. (2015) analyzed these suggestions and identified four important themes: reflexive social learning, critical phenomenology, socio-cultural activity, and new social movement. Many researchers suggest that it is not only the problem that students need to solve but it is a more systematic and reflexive way of thinking and acting, taking into consideration

that the world is changing continuously (Laclau & Mouffe, 1985; O'Donoghue et al., 2007; Wals & Heymann, 2004; Wals & Schwarzin, 2012). Regarding the critical phenomenology, there is a need to transgress the boundaries between the inner and outer worlds of learners as a means of transformation (Lotz-Sisitka et al., 2015; McGarry, 2014; Sack, 2011; Zumdick, 2011). Learning that involves the phenomenological experience of learners should provide opportunities for inquiry and exploration with democratic participation and social interaction that do not separate object and subject or place and person (Greenwood, 2009).

Zumdick (2011) described the world as a huge laboratory where people are always looking for a new way of living and participating using new materials and new techniques; however, this laboratory should change from focusing on the technical, scientific, political and economic sense to focus on the individual's inner ability and potential that investigates the inspiration, imagination and intuition. For the socio-cultural activities, there is an emerging body of post-Vygotskian research that focuses on the socio-cultural techniques of transformative learning (Lotz-Sisitka et al., 2015). Other studies that used this approach have stated that transformative learning can lead to increased cognitive skills in the learning process that take into account the power relation to the social interactions (Mukute, 2010). Regarding the social movement, they are currently dealing with the continuities of a lived experience of "racism, exclusion, and epistemic and environmental injustices" (Lotz-Sisitka et al., 2015, p.77). The challenge here is that teaching should emphasize the struggles of society and real-world issues (Chaves, Wals & Macintyre, 2015).

Cranton (2006) stated that transformative learning is a process of examining, questioning, validating, and revising our perspectives. The commonality between authentic assessment and transformative learning is the critical self-reflection, which is an important phase in providing opportunities to critique assumptions and worldviews for examination that either accept or reject those assumptions (Fook & Sidhu, 2013). The authentic assessment methods go well with transformative learning due to the commonality in the processes where both of them emphasize the role of critical reflection, rational discourse and centrality of experience (Fook & Sidhu, 2013). This will lead the focus to the three types of learning (emancipatory, instrumental, and communicative learning) that are embedded within transformative learning and authentic assessment, where each type of learning develops certain skills that will lead to the transformation in students' frame of reference (Ashford-Rowe, Herrington & Brown, 2014). In addition, the transdisciplinary curriculum design emphasized the role of three important domains (cognitive, psychomotor, and affective domains) that require the same three types of learning and lead to the skills development (Sipos et al., 2008).

The emphasis on the transformative learning and authentic assessment shift the focus onto what content is taught and how it is taught which highlights the importance of the transdisciplinary curriculum (Fook & Sidhu, 2013). The transdisciplinary curriculum using authentic assessment in the light of transformative learning shifts the focus from what students need to know to what they are able to do (McTighe & Wiggins, 2004). Vasquez, Sneider & Comer (2013) described the development of the content and skills in the transdisciplinary curriculum to be partly determined by the teacher and partly determined by students. In addition, the organization of problem-based or project-based tasks to be in a real-life context and driven by students' questions (Vasquez, Sneider & Comer, 2013). The disciplines' boundaries are de-emphasized as students work on real-life problems or projects where procedures are to be at least partially led by students and partially led by teachers, and in time should be shifted to be totally led by students (Vasquez, Sneider & Comer, 2013). Concepts and skills in the transdisciplinary curriculum are assessed by combining methods from different disciplines that involve students in authentic assessment tasks where they are engaged in critical self-reflection, rational discourse, and centrality of experiences (Vasquez, Sneider & Comer, 2013).

The framework suggested for the authentic assessment with the transdisciplinary curriculum is the backward design process which starts with standards and assessments, then the learning activities will be planned accordingly (Tomlinson & McTighe, 2006). The transdisciplinary assessment tools depend on the purpose of assessment to be summative, formative, or diagnostic (Vasquez, Sneider & Comer, 2013). The assessment tasks stated are: checklists, rubrics, classroom tests, maps, self-assessment, peer-assessment, graphic organizers, concept maps, portfolios, and conferences (Vasquez, Sneider & Comer, 2013). The authentic performance tasks that are presented at the beginning of a new unit provide a meaningful vision of the targeted learning goals for students (Vasquez, Sneider & Comer, 2013). The authentic performance tasks can be used as summative assessment that frames meaningful performance. The authentic assessment tasks do not require recalling of information but rather students need to apply what they have learned into new situations so they reveal deep understanding and skills (Vasquez, Sneider & Comer, 2013). In addition, using rubrics to present the criteria of success to students at the beginning of the unit help students understand what they are being asked to do, as well as the performance levels (Vasquez, Sneider & Comer, 2013). Furthermore, students need to be offered appropriate choices of assessment which allow them to rely on their strengths (Vasquez, Sneider & Comer, 2013). Examples of assessment choices are: presentation, project, research, display, notebook, or portfolio. The most important element in authentic assessment that leads to transformational

learning is the continuous feedback provided to students that should meet some criteria: to be timely specific, understandable to the receiver, and designed to allow for improvement (Wiggins, 1998). The most effective learners are those who set their learning goals, employ proven strategies, observe, and self-assess their work (White & Nitkin, 2014). This lies in the emancipatory learning where critical reflection is considered to be the core of developing critical thinking and being self-directed learners. The authentic assessment should focus on how well the students have mastered the knowledge and skills, not when they mastered them (Vasquez, Sneider & Comer, 2013). Mastering the knowledge and skills as well as transferring them into new situations fall in the core of centrality of experience in instrumental learning where students' problem-solving, creativity and innovation skills are developed. Here teamwork is of crucial importance, where they frequently collaborate in their work and communicate to reflect on their learning, giving constructive feedback, receiving help and guidance from each other, supporting the efforts of peers, and celebrating their victories (Vasquez, Sneider & Comer, 2013). This lies in the communicative learning where rational discourse is set in the core of developing students' communication and collaboration skills. At the end, assessment and instructions are so closely joined that it is impossible to distinguish one from the other and they work to transform students' learning when they are used in their meaningful higher level (authentic assessment and transdisciplinary curriculum). (Vasquez, Sneider & Comer, 2013).

The continuous changes in the world challenge teachers to focus on developing students' skills in real-life applications in addition to the focus on the core subjects (Merilainen & Piispanen, 2013). The 21st Century Civil Skills Pedagogical Content Knowledge (21st Century CSPCK) attempts to identify the nature of pedagogical knowledge required to shift learning from traditional to transformational (Merilainen & Piispanen, 2013). This lies in the high complexity of teaching and learning activities while considering the role of 21st century skills (Ashe & Bibi, 2011). The traditional schools assume that learning is the students' responsibility however the transformational schools share learning via a professional learning community that includes and goes beyond teachers and students (Chaltain, 2011). Regarding students' achievements, the traditional schools focus on and emphasize test results while the transformational schools focus on students' aspirations and life options (Merilainen & Piispanen, 2013). According to Drake and Burns (2004), learning experiences should be relevant to students' interests and allow them to manage well in multiple academic areas.

The 21st century skills are an essential key element together with the pedagogical knowledge and content knowledge of planning, teaching and learning (Merilainen & Piispanen,

2013). Merilainen & Piispanen (2013) stated that the traditional pedagogy named as "subject or theme based learning" and the transformational pedagogy named as "contextual pedagogical approach to learning" differ in the role of curriculum, teachers and learners in implementation. From planning to assessment, the traditional pedagogical model has some characteristics regarding: basis for planning; tools for planning; learning situations; and assessment (Merilainen & Piispanen, 2013). The teacher role in basis for planning is to focus on and prepare the core curriculum, textbooks, handbooks, while students are not involved in this planning. As tools for planning, teachers use different subject contents, learning materials, games, handbook, textbooks, multidisciplinary integration, and sometimes external structures, while students are also not involved in this planning. At the beginning of the process, teachers are driving the teaching and learning process while students are receiving information and acting according to teachers' driven instructions. During the process, teachers usually interact with students or students interact with teachers while the weak students will not work hard or will leave the task. At the end of the process is testing the knowledge and giving feedback to students with test numbers while students are all having the same tasks in the end.

The assessment type emphasized is assessment of learning that is done by the end of the unit where teachers know the criteria and provide feedback while students do not know the assessment criteria and are divided into weak and strong learners according to success in different tests. On the other hand, the transformational learning from planning to assessment has different characteristics (Merilainen & Piispanen, 2013). The teachers' roles in planning are based on students' interests, real-life applications, and life habits and skills, while students' roles are active in the planning and have their own profiles. The tools used for planning are the 21st Century Civil Skills Pedagogical Content Knowledge, the transdisciplinary approach, and focus on real-life experts while students are also active in this stage and their opinions are considered. In the beginning of the learning process, teachers are motivators and facilitators; they present the project, mission, aims, and assessment criteria while students set the goals and have their personalized learning plans. During the process, teachers are leaders of the learning community, give students feedback through discussions, support them when needed, and are aware of students' strengths and weaknesses. Students, during the learning process, are working collaboratively as a team, have multiple ways to show learning, use multiple technology tools, and learn by working with real-life tasks. At the end of the learning process, assessments are seen as learning, teachers engage students in discussions, and students build exhibitions to show what they have done during the learning process. The assessment here is an integral part of learning. The criteria are visible to everyone and presented to students at the

beginning of learning. Assessment as learning is toward life options using authentic tasks. Students are aware that they can learn differently and have opportunities to choose their assessment task.

The transformational learning highlights the preparation of the future workforce using transdisciplinary integration (Merilainen & Piispanen, 2013). In the transdisciplinary approach, teachers organize the curriculum based on students' questions and arrange instructional activities in the form of authentic assessment tasks (Drake & Burns, 2004). Accordingly, the operational culture of the school reflects the operational culture of the external world. In the transformational learning environment, students develop their life skills while being engaged in authentic assessment tasks that are used as learning (Merilainen & Piispanen, 2013). It is essential to examine the transdisciplinary curriculum where there is blurring between the borders of different subjects and the focus will be only on the real-life applications that students will be familiar with (Piispanen & Merilainen, 2013; Sahlberg, 2011; Zhao, 2011). At the end, the teachers set the core of transformational learning where they are acting as: curriculum specialists in connecting subjects and selecting topics related to real life; pedagogical specialists who are able to create meaningful and enthusiastic learning tasks; and contact experts whenever needed to give authentic learning experiences (Kumpulainen et al., 2011).

Students in this learning environment are constructing their own knowledge while they are collaborating together where the dialogue between students-students and teachers-students takes place (Merilainen, Piispanen & Valijarvi, 2013). Students are more motivated to learn when learning tasks are connected to real-life, interesting for them, challenging, and enable them to think creatively (Merilainen & Piispanen, 2013). It is essential not to ignore the students' needs and how they learn at their best. The transformational learning process enables diverse students to work according to their best ability (Merilainen & Piispanen, 2013). Providing students with the goals and assessment criteria will guide students step by step toward their learning paths and these paths are differentiated in the way that best suits students' needs (Merilainen & Piispanen, 2013). When the transdisciplinary curriculum is learned in authentic assessment tasks, it gives the opportunity for students to satisfy their learning styles through the learning processes (Merilainen & Piispanen, 2013). The learning styles are considered to be an input of learning where they should be considered in students' activities, while multiple intelligence is considered to be an output of students' learning (Ornstien & Hunkins, 2014).

1.7 Scope of Work

The purpose of this study is to investigate the impact of designing a transdisciplinary STEAM curriculum using authentic assessment on transforming student learning in a vocational institute in UAE. A multiphase mixed method is used in this study with two different phases that aim to extend the depth and breadth of the study (Johnson & Christensen, 2012). The first phase of the study is a sequential exploratory mixed method that aims to investigate the extent of aligning a transdisciplinary curriculum with authentic assessment and the curriculum team's perceptions. The data was collected qualitatively using document analysis of the curriculum lesson plans and quantitatively using a questionnaire for the curriculum developers and teachers. The participants in this phase were thirty participants selected randomly from a shared characteristic group. The results were analyzed and interpreted. The second phase of the study is a sequential explanatory mixed method that aims to know the cause and effect of using emancipatory, communicative and instrumental learning with grade 12 students. The data was collected quantitatively using a quasi-experiment pretest-posttest control group" with grade 12 students with a randomly selected sample. The sample was selected equally between males and females to form a total of eighty students. The results of this phase were analyzed and interpreted separately. Finally, the results of the two phases are compared and integrated in categories using the framework of the study to fulfill the main purpose.

1.8 Structure of Thesis

This study consists of five main chapters: Introduction, Literature Review, Methodology, Data Analysis, and Discussions, Conclusions and Recommendations. This chapter was the introduction that covers the rationale, significance, background of the study, problem statement, purpose and research questions, and the scope of work. The next chapter covers the theoretical framework, conceptual framework, and literature review. The theoretical framework discusses the main theories used in this study, such as cognitive constructivism, social constructivism, constructive alignment theory, and transformative learning theory. The conceptual framework discusses with the diagram the framework used to guide this study starting with the theories and build-up using previous studies. Then, the literature review relates to the transdisciplinary curriculum, STEAM education, authentic assessment, alignment between the transdisciplinary curriculum and authentic assessments, transformative learning, emancipatory, communicative and instrumental learning. The results of previous studies are

also documented in the second chapter. The third chapter outlines the methodology of the study where the research design, population, sample, instrumentation, data collection method, validity and reliability, pilot study, and ethical considerations are presented. The fourth chapter presents the data analysis of each phase of the study separately. This chapter will take the reader through the analysis of the captured data using tables, diagrams and quotations from participants in order to enhance the reader's understanding. The results of each phase are analyzed and interpreted separately. The fifth chapter summarizes the study, presents the comparison of the results in two phases, the discussion of the findings and the integration of results; has recommendations, limitations and challenges of the study, and suggestions for further research.

Chapter Two: Literature Review

The purpose of this study is to investigate the impact of designing a transdisciplinary STEAM curriculum and authentic assessment on transforming students' learning in a vocational institute in UAE. In this chapter, a literature is documented and reviewed regarding transdisciplinary curriculum design, adding Art to STEM, authentic assessment, transformative learning, and the alignment of a transdisciplinary curriculum and authentic assessment. Finally, the emancipatory, communicative and instrumental learning are discussed. The conceptual framework is built on the relationship between theories using research studies to guide this study.

2.1 Conceptual Framework

The conceptual framework of the study is based on previous researches that confirm or disconfirm previous theories mentioned in the theoretical framework.

Constructivism is an orientation of the framework that Mezirow (1997) built his theory upon, the idea that students construct meaning based on their previous experiences. Constructivism is the backbone of what Drake and Burn (2004) mentioned about authentic assessment, that it is the primary assessment concern of transdisciplinary units. Accordingly, Drake's model of Know, Do and Be (KDB) that identifies each stage of designing a curriculum (Drake & Reid, 2010) is used in this study. "Know" is the stage of finding the theme and aligning the curriculum to the assessment; "Do" is the process of learning that involves the critical thinking, independent learning, creativity and innovation, problem-solving, inquiry, self-direction, collaboration and communication; and "Be" is the beliefs, attitudes and values that will lead to the transformation of students' learning. Bigg's constructive alignment theory (1996) proposed to align the desired outcomes, assessment and learning activities. The transdisciplinary curriculum and authentic assessment tasks are features of transformative learning (Henderson & Gornik, 2007; Lovering, 2012; Saudelli, 2012).

The "Know" in this conceptual framework represents the alignment of the transdisciplinary STEAM curriculum to the authentic assessment. Lewis (2017) stated in a previous study that the constructive alignment integrates between: the desired outcomes of authentic tasks that need to be clear and explicit; the design of constructivist learning activities; and the co-construction of integrated knowledge. This is supported by Bass (2014) who described the authentic assessment tasks as social and cognitive pedagogies that engage

learners in procedural learning processes. Accordingly, the authentic assessment tasks are best aligned to the transdisciplinary curriculum due to the flexibility of designing learning activities that develop students' 21st century skills (Drake & Burns, 2004; Drake & Reid, 2010, 2017; Drake & Savage, 2016; Drake et al., 2015). The transdisciplinary STEAM curriculum requires students to be engaged in constructivist learning activities that enhance their skills and lead to transformative learning (Costantino, 2018; Gettings, 2017; Gross &Gross, 2016; Guezy, Moore & Harwell, 2016; Herro & Quigley, 2017; Liao, 2016; Singleon, 2015; Perignat & Katz-Buonincontro, 2018; White & Nitkin, 2014). Another relationship occurs between the authentic assessment and transformative learning where critical reflection, rational discourse and procedural learning take place (Ashford-Rowe et al., 2014; Cheng, 2015; Fook & Sidhu, 2013; Heddy & Pugh, 2015; Owen, 2016). The authentic assessment tasks have a positive impact on students' learning, motivation, self-regulation and metacognition (Villarroel et al., 2017).

The "Do" in this conceptual framework represents the students' skills that are acquired through three types of learning: emancipatory, instrumental and communicative learning. Skills that lead to transformation in students' learning should be acquired through these three types of learning (Greenhill et al., 2018; Owen, 2016; Provident et al., 2015; Singleton, 2015). Students' transformative education involves instrumental, communicative and emancipatory learning (Mezirow, 1994, 2009). A recent study emphasized that the design of authentic tasks using integrated knowledge can transform students' ways of knowing through being engaged in instrumental, communicative and emancipatory learning (Greenhill, Richards, Mahoney, Campbell & Walters, 2018). The "Be" in this conceptual framework represents the transformation on students' learning where there is change in their frame of references (habits of minds, mindsets, and perspectives transformation). Transformational learning occurs not only in students' behaviour but also in their ways of knowing (Berger, 2004; Dix, 2016; Kegan, 1994; Klein, 2018). To act differently, have a deeper self-awareness, be more open to different perspectives, and experience a deep shift in worldview are outcomes of transformative learning (Klein, 2018; Lawrence & Cranton, 2009; Stuckey, Taylor & Cranton, 2013). It was recommended in previous studies that educators should emphasize the occurrence of self-reflection, critical discourse and procedural learning to promote transformative learning (Browning & Solomon, 2006; Buchman, 2012; Lawrence, 2012; Mann, 2011). Several studies show a strong relationship between an integrated curriculum and authentic assessment that has a positive impact on transforming students' learning (Breunig, 2017; Ghosh, 2017; Greenhill et al., 2018; Merilainen & Piispanen, 2013; Naidoo & Kirch, 2016; Turner, 2015; Vasquez, Sneider & Comer, 2013).

It is interestingly important to note that Sipos et al. (2008) suggested a similar framework of learning called the "Head, Hands and Heart Model" that leads to transformational learning. The Head refers to the engagement of learners in the cognitive domain (emancipatory learning) through academic studies, inquiry and understanding of concepts (Singleton, 2015). The critical reflection of students results in a change in their frame of reference, providing an emancipatory dimension to transformative learning (Greenhill et al., 2018; Lewis, 2017). "Hands" refers to the psychomotor domain (instrumental learning) which is the development of skills and physical work (Singleton, 2015). The instrumental learning made a connection between theory and practice where students' roles are adopted (Breunig, 2017; Greenhill et al., 2018). Heart refers to the affective domain (communicative learning) that forms values and attitudes that are translated into behaviours through communication, collaboration and self-direction (Singleton, 2015). The communicative learning allows students to demonstrate the ability to consult and interact effectively (Greenhill et al., 2018). Mezirow's transformational theory provides a theoretical lens to understand how students experience instrumental learning (problem-solving, creativity and innovation processes); communicative learning (understanding others' perspectives through communication and collaboration); and emancipatory learning (critical reflection on their independent learning) (Mezirow, 1994, 2009). The three major elements of transformative learning are: critical reflection on learners' assumptions; dialectic discourse to validate new perspectives; and the context of learning experiences (Mezirow, 2009; Synder, 2008; Taylor, 2007). Students who are engaged in these three types of learning experienced a disorienting dilemma where critical assessment of their beliefs, feelings and assumptions, and dialectical discourse with peers, occurred (Greenhill et al., 2018; Klein, 2018).

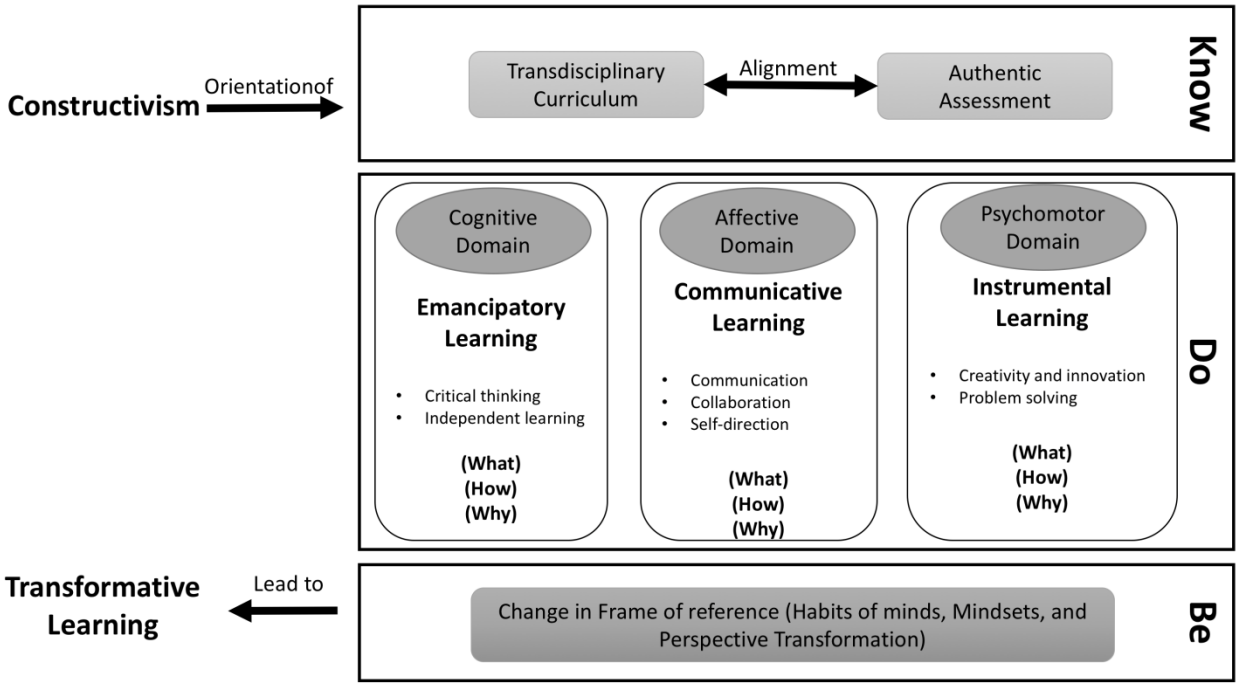

Figure (2.1): The Conceptual Framework that guided the study

2.2 Theoretical Framework

Curriculum has been defined broadly as dealing with learners' experiences (Dewey, 1902). This means that anything planned inside or outside the school is part of the curriculum. The external boundaries of the curriculum are called the curriculum foundations that are implied in philosophical, psychological, historical, and social foundations (Ornstien & Hunkins, 2014). The focus of this study is on the philosophical and psychological foundations because these are set as roots for the transdisciplinary curriculum and authentic assessment that lead to transformative learning.

The psychological foundation aims to shift the focus from the knowledge to developing students' skills, through the student-centred approach in a constructivist environment. The psychological foundation is concerned with the way students learn and the way it contributes to the design and delivery of the curriculum (Ornstien & Hunkins, 2014). Constructivism addresses the nature of knowledge and nature of learning (Howe & Berv, 2000). It treats students as active learners who are involved in the process of thinking and learning where they must adopt and reform or transform knowledge (Brooks & Brooks, 1993). Metacognition with regards to constructivism means that learners are aware of the process while acquiring and using knowledge (Duffy & Jonassen, 1992). It is important to note that reflection is essential in the cognitive process, where learners construct knowledge and understanding; question themselves and their views; interpret and interact with their world; and draw on their past and

present perceptions by reflecting on their learning (Ornstien & Hunkins, 2014). This is how transformation of students' learning occurs.

There are two main approaches of constructivism: cognitive and social constructivism. Cognitive constructivism which is based on Piaget's theory concentrates on the importance of the mind in learning, while the social constructivism which is based on Vygotsky's theory focuses on the social interactions between learners (Fosnot, 1996). Piaget's theory of cognitive development lies in the way learners construct their own knowledge instead of receiving it (Piaget, 1953). Assimilation, accommodation and equilibration are processes included in Piaget's theory which students go through in a search for balance (Wadsworth, 2004). On the other hand, social constructivism is when students interact socially along with a personal critical thinking process (Vygotsky, 1962). One of the main elements of Vygotsky's theory is the Zone of Proximal Development (ZPD) where learners learn easily when others are involved and interact with them (Vygotsky, 1962). Cognitive constructivism heavily emphasizes the reasoning ability of learners and how they interpret knowledge based on their personal experiences, while social constructivism considers the variables of social interaction, culture and language that affect the ways learners learn (Powell and Kalina, 2009) which are all considered in the three types of learning. In the constructivist approach, students construct knowledge through a sequential development and scaffolding of each person's cognitive abilities, unlike behaviourism and cognitivism where rules and knowledge are acquired (Fosnot, 2005; Greene, 2005).

2.2.1 Cognitive Constructivism

Piaget's cognitive processes (assimilation, accommodation and equilibration) are essentials in the way students learn and should be considered in instructional activities (Ornstien & Hunkins, 2014). Assimilation is organizing curricula and teaching new experiences that are compatible with existing experiences. Accommodation is to move from the concrete experiences to concepts and principles. Equilibration is classifying and understanding new relationships. Equilibration is considered to be the shift toward transformative learning where students use what they have learned and transfer it to new concepts (Taba, 1962; Tyler, 1949). Piaget's cognitive process is set as a basis for Tyler's three methods of organizing learning experiences, where the focus is on continuity, sequence and integration (Ornstien & Hunkins, 2014). Continuity is where skills and concepts should be repeated within the curriculum and provides opportunities for these skills to be continued.

Sequence is the progressive development of the curriculum where each successive experience builds upon the previous one and continues to develop deeply and broadly. Integration is where the curriculum elements should be unified and not isolated as separate subjects and so will be taught as a single course. Dewey used the term continuity and clarified that what students learned becomes an instrument of understanding and dealing effectively with new situations, which is at the heart of transforming students' learning (1938). In addition, Bruner agreed with Piaget and Dewey about the continuity of the subject matter and mental operations that can be continually deepened using a progressive and complex process that consists of acquisition, transformation, and evaluation (Bruner, 1977). The acquisition stage is similar to assimilation which is the grasping of new information that might build on or substitute previous information. The transformation stage is overlapping with accommodation, that lies in translating what students learn into another form. The evaluation stage is closely corresponding with equilibration and determines whether information is appropriate to deal with a particular task or problem.

2.2.2 Social Constructivism

Social-cultural theory is also known as social constructivism; it describes learning to be more holistic and relevant, that it enables students to make meaning of the social and cultural worlds they inhabit (Efland, Freedman & Stuhr, 1996; Greene, 2005). Lev Vygotsky's theory is not only focusing on cognitive theory but also on the socio-cultural development (Bruner, 1990). Vygotsky emphasized the role of communicative learning in the development of children where the socio-genetic process is shaped by the individual's interactions, dialogue and play with the culture (Moll, 1990). Furthermore, Vygotsky (1978) argues that students' zone of proximal development (ZPD) is what students are capable of learning in collaboration with more capable peers. For the socio-genetic development, language was the primary tool invented by humans to enable organization of thinking through communication and collaboration. Via instruction and communication, learners can be pulled to a higher level (Bereiter & Scardamalia, 1992). Based on the above-mentioned theories, cognitive and social constructivism are at the heart of emancipatory, communicative and instrumental learning, where learners are actively engaged in the process of learning using a dialogue to communicate.

2.2.3 Constructive Alignment Theory

The internal boundaries of the curriculum are the curriculum domains, such as curriculum design, development, implementation and evaluation (Ornstien & Hunkins, 2014). The focus of this study is on the curriculum design that will set the connection between the transdisciplinary curriculum and authentic assessment. Every school has a planned and formal curriculum but it is increasingly important to note the importance of the unplanned and hidden curriculum (Ornstien & Hunkins, 2014). The planned curriculum focuses on goals, objectives, content and the organization of teaching and learning activities. The unplanned curriculum is dealing with the socio-psychology interaction between students and teachers that lies in their feelings, attitudes and behaviours. This implies the humanistic approach that focuses on the personal and social aspects of curriculum and instruction. Humanistic approach highly focuses on the subject matter's artistic, physical, and cultural aspects; the need of self-reflectiveness and self-actualization among learners; and overlooks the socio-psychological dynamics of the classroom (Ornstien & Hunkins, 2014). This view is rooted in progressive philosophy and the student-centred approach (Dewey, 1934; Kliebard, 1989; Schwab, 1969; Taba, 1962).

In constructivism, students are active learners and able to investigate, construct new understandings, and transform knowledge on their own (McDonald & Van der Host, 2007). As a result, the constructive alignment theory is raised to facilitate the construction of new understanding of reality for learners by aligning learning outcomes, teaching and learning, and assessments (Biggs, 1996). It is essential for curriculum designers to consider the end (desired outcomes) in order to design for learning in the right direction (Wiggins & McTighe, 2005). The "backward design" is a way used in designing curriculum by following three steps: identifying the desired outcomes; assessment criteria and methods; and instructional activities that lead to the transformation of students' learning (Wiggins & McTighe, 2005). In other words, it is to identify what the students need to know (knowledge) and be able to do (skills), then plan for the instructional activities, and all should be aligned to real life (Biggs, 1999). The constructive alignment theory is extracted by Biggs (1996) from the constructivist approach of leading the teaching and learning process by focusing on the knowledge students should acquire and aligning it with the assessments. The design of the curriculum through the constructive alignment should be done in three stages (Biggs and Tang, 2007). First, identify the learning outcomes and understand the complexity of integrated knowledge and skills students need to master. Second, develop the authentic assessments in alignment with the desired outcomes. Finally, develop the instructional activities that engage students in a process

of using acquired knowledge, mastering skills, and transforming their learning to form innovative products that are related to real life. The assessment here is to provide students with feedback that allows them to critically reflect on their learning and should vary authentically (Rust, 2002). The constructive alignment is used effectively in many studies with different aims. It is used to form a template in order to map the curriculum in relation to students' skills (Sumison & Goodfellow, 2004); and evaluate the curriculum design and planning (Frazer & Bosanquet, 2006; Larkin & Richardson, 2013; Leigh et al., 2012).

A radical student-centred design of curriculum integration was developed by Dewey with the focus on students' interests and community rather than subject areas (Dowden, 2007). The heart of curriculum design is the focus on the reconstructing of learners' experiences that form the conception of integration at the personal level (Dewey, 1933). Learning by doing is essential for students where they should actively engage in inquiry and experience the subject matter (Dewey, 1907). The promotion of integration at a social level by developing learning in the classroom as a society in miniature helps students to develop the skills and attributes needed in wider society where they work collaboratively, solve real-life problems, and build self-discipline (Dewey, 1907). On the other hand, Dewey (1997) emphasized the role of authentic assessment, where critical reflection is essential within the process of learning in real-life situations that are implied in intellectual, personal, and dialogue reflection. Dewey (1997) proposed a didactic model of learning through creating a connection between reflection and actions where reflective thinking allows learners to move back and forth in the learning process.

2.2.4 Transformative Learning Theory

The transformative learning theory is based on the constructivism that is implied in constructing or creating new knowledge and making meaning of learners' life toward learning (Mezirow, 1997). It is important to note that Mezirow criticized the structure of the constructivist approach where some learners need various degrees of structured teaching to learn (Kaufman, 2003). Mezirow (1997) pointed out that a transformation of students' learning takes place when changes in their frame of reference occurs, which includes points of view and habits of mind. Change in the points of view comes through the transforming of individuals' beliefs, value judgments, and attitudes. It is easy to change because it is based on empirical evidence. In contrast, habits of mind are the ways in which learners think, feel and act in the world. It is not easy to change these because it needs learners to go through the process of

reflective thinking (Mezirow, 1997). The process of transforming learning theory involves transforming frames of reference through critical reflection on assumptions within emancipatory learning, validating contented beliefs through discourse within communicative learning, taking actions on one's reflective insight, and critically assessing it within instrumental learning (Mezirow, 1997).

Critical reflection refers to the self-examination and awareness of others (Owen, 2016). It is used in the sense of questioning and brainstorming how and why we think certain things in certain ways (Cranton & Carusetta, 2004). In other words, it is the purposeful critical analysis of knowledge and experiences that allows learners to achieve deeper meaning and understanding (Mann et al., 2007; Owen, 2016). Rational Discourse refers to the meaningful communications with others in a process of specific dialogue that is intended to validate an individual's experiences and ideas (Mezirow, 1981; 1997). Mezirow refers to it as communicative learning, that develops individuals' communicative competence through negotiating their own purposes, values and meanings rather than accepting those of others. However, the awareness of others' assumptions, purposes and intentions is considered to be an important aspect of communicative learning (Owen, 2016). It is an inductive process of learning (Mezirow, 2003). The critical reflection and discourse lead to the third stage which is the transformation of the perspective (Provident et al., 2015). It has been referred to as instrumental learning where the learners are involved in processes that allow them to make and implement plans that bring out new ways of defining the world. In this stage learners are integrating knowledge to real life, forming a new frame of reference (Owen, 2016). It is a hypothetically deductive process (Mezirow, 2003). This is aligned with Dewey (1907), Freire (1970) and Knowles (1980) who promoted pedagogies that allow students to be active learners who drive and use knowledge rather than receive it. Therefore, skills such as motivation, self-discipline, and self-direction are essential in order to be successful learners. Kolb (1984) stated that true knowledge is created through learners' experiences; however, Dewey (1938) pointed out that investigative learning transforms feelings and attitudes to purposeful actions whereby learners learn by reflecting on their own experiences. Dewey (1933) stated the importance of enriching possibilities of experiences to change learners' ways of viewing the world and how to be in the world that is transformative.

Transformative learning is a challenging goal for educators who want to make a significant shift in students' lives (Heddy & Pugh, 2015). Transformative learning is not the same as transformative experience (Heddy & Pugh, 2015). Transformative learning is defined as the shift of students' worldview, and it is difficult for teachers to retain such an important

goal (Heddy & Pugh, 2015). However, transformative experience is to create micro changes in students' perspectives which is more manageable in classrooms, and the accumulation of small changes can lead to the transformative learning which is considered as major change (Boyd, 2009; Heddy & Pugh, 2015). It is proposed for teachers to focus on the small scale of transformative learning as well as the large scale of transformative learning (little t and big T transformation) (Heddy & Pugh, 2015). Pugh (2011) used the construct of transformative experience as a framework for applying little t transformative learning approach. Transformative experience occurs when students apply the learning concepts to everyday life in a way that facilitates changes in their perceptions and generate values (Pugh, 2011). Transformative experience is known as a micro form of transformative learning that students are engaged in during learning, but which does not necessarily lead to a holistic change in learners' worldview (Pugh, 2004). In other words, transformative learning involves a deep fundamental change in learners' perspectives and a fundamental shift in students' personality (Boyd, 2009). As a result, the transformative learning has been seen as the "big T" which is described as a big shift in students' perspectives (Heddy& Pugh, 2015). In contrast, the transformative experience has been seen as "little t" which is described as the small shift in students' perspectives and the continuous use of it will lead to transformative learning (big T) (Heddy& Pugh, 2015). The transformative experience highlights a Deweyan perspective on pragmatic education which is the relevance of education to everyday experience and aesthetic experience to science education (Pugh, 2011). This experience will lead the focus to three characteristics of transformative learning: motivated use, perception expansion, and experiential value (Heddy & Pugh, 2015). Motivated use is the use of students to the learning concepts to everyday life; perception expansion occurs when students change their views of everyday experience due to learning; and experiential value occurs when learners feel the value of content for its ability to influence experience (Heddy & Pugh, 2015; Heddy & Sinatra, 2013; Pugh, 2011). It is not expected that all students will have a transformative experience in their learning but it is reasonable to have most of the students to undergo some teaching experience while engaged in their learning (Heddy & Pugh, 2015). At the end, transformative learning and transformative experience are similar where both include alteration of the way in which they perceive the world (Heddy & Pugh, 2015). In contrast, the distinction between them is that transformative learning is a much deeper change in students' life while transformative experience occurs on a much smaller scale (Heddy & Pugh, 2015). However, the repeated use of transformative experience is much easier for teachers to apply in their classrooms and leads to the deep change in students' lives (Transformative learning) (Heddy& Pugh, 2015).

The significant problem is that teachers feel the tension between facilitating transformative learning and the increase of the accountability of international assessments that force them to teach to the test (Heddy & Pugh, 2015). The constant internal and national assessments reduce the amount of time that teachers have to transform students' learning (Heddy & Pugh, 2015). In addition, few teacher education programmes focus on how to facilitate transformative learning and thus, teachers do not have the skills required to provide such instructions and facilitations (Heddy & Pugh, 2015). As a result, it was suggested to use the transformative experience continuously that will lead to the deep transformation in students' learning which is easy for teachers to use, where the smaller is more manageable (Pugh, 2011). Pugh and his researcher colleagues proposed a model of "Teaching for Transformative Experiences" that encompasses three design principles: "framing content in its experiential value; scaffolding re-seeing; and modelling transformative experience" (Heddy & Pugh, 2015, p.55). Framing involves the purpose of learning where powerful ideas are tried out (Pugh & Phillips, 2011) and using content ideas to view the world differently (Wong et al., 2001). Scaffolding re-seeing is helping the students identify everyday objects that could be re-seen and coaching them throughout re-seeing attempts through providing opportunities to share their new experiences (Pugh et al., 2010b). Finally, modelling transformative experiences refers to a focus of illustrating the shared personal experiences and values through the lens of the content and expressing passion for the content (Heddy & Sinatra, 2013). Another teaching strategy that is effectively used to guide students' transformative experience is called Use, Change, Value (UCV) discussions (Heddy, Sinatra & Seli, 2013; Heddy, Sinatra, Seli & Mukhopdhyay, 2014). Researchers have found that this strategy has a large impact on other outcomes where transformative experience is aligned to the learning outcomes (Heddy & Sinatra, 2013; Pugh et al., 2010a); transfer of learning to new situations (Pugh et al., 2010b); and transfer of learning strategies to other disciplines (Heddy et al., 2014). Furthermore, transformative experience is linked to other outcomes such as positive emotions (Heddy & Sinatra, 2013); development of interest (Heddy et al., 2014); and academic and career choices (Pugh et al., 2014).

Mezirow & Associates (2000) agreed with these assumptions where they theorize the differences between transmissional, transactional, and transformational learning. The transmissional learning occurs when teachers transmit knowledge to students through direct instructions. Transactional learning happens when students have valuable experiences that modify their perceptions; and the multiple transactional will lead to transformative learning as transactional learning is defined later by transformative experience (little t) (Heddy & Pugh,

2015). Pooley (2015) gave a framework of four generalizations that help in transforming students' learning. The first generalization is called "the deep end", based on Dewey (1938) who pointed out that experience alone is not enough where not all learners are in the same level of education. It is the deep engagement in learning as well as the experience students gain through being involved in real-world problem-solving (instrumental learning) (Pooley, 2015). This "deep end" experience is long lasting and has a positive impact on students' learning (Pooley, 2015). The second generalization is called "part of who I am" which lies in the value, motivation and feelings of learners where they feel that the work they do is part of them which creates a strong connection of students to their work (Pooley, 2015). Hostler (2011) supports this idea that students believe in themselves when they are deeply engaged in their learning processes. In addition, Dewey also stated that when learners trust their own values this is because they have experienced them before (Hostler, 2011). This in its term leads learners to transfer what they have learned to new situations where they are thrown in the deep end and are drawing on their values alone (Hostler, 2011). The third generalization is called "like-minded people" where there is an interdisciplinary learning environment with a strong sense of teamwork, shared ambitious, tolerance, creativity, and being part of a community practice (Pooley, 2015). Students learn in groups and take responsibility for solving new and technically challenging issues where learning has no end and continues to influence others (Wenger et al., 2011). The last generalization is "doing the right thing" where morality and ethical consideration are crucial in students' decisions (Pooley, 2015). Leading students' learning toward research, testing, and taking radical approaches helps to form a professional stance on sustainability (Pooley, 2015).

Taylor and Cranton (2012) pointed out that transformative theory is based predominantly on hundreds of qualitative studies with little focus on the positivist research beyond mixed-method study. Cranton and Hoggan (2012) mentioned different ways of evaluating transformative learning that includes quantitative data collection of assessing transformative learning and outcomes of the process. From the positivist perspective, Mezirow (1996) mentioned that instrumental learning is focusing on learning through the problem-solving and determination of the cause-and-effect relationship based on empirical analytic discovery. However, the focus of communicative learning is basically about understanding the others' beliefs, values, feelings, and moral decisions through effective communication. Regarding emancipatory learning, Mezirow (1981) emphasized the role of critical reflection that refers to questioning the assumptions and beliefs, based on prior experience. This is basically focusing on the instrumental learning through objective reframing that intends to

improve performance in addition to critical self-reflection of assumptions that focuses on psychological and cultural limitations through subjective reframing.

2.3 Transdisciplinary Curriculum

Progressivism and reconstructionism are two major philosophical foundations of the curriculum that will be the focus of this study. Progressivism and reconstructionism both stem from the pragmatist view where the focus is on the process and the way students learn (Dewey, 1916). Progressivism aims to promote democratic and social living within individuals where the focus is on active and relevant learners (Ornstien & Hunkins, 2014). Teachers here are guiding students through solving problems and scientific inquiry where the curriculum focus is based on students' interests, addressing human problems, integrated subjects, activities and projects (Dewey, 1934). The reconstructionist view aims to improve and reconstruct society to educate for social reform where the focus is on skills and subjects needed to identify real-world problems. Teachers act as project director or research leader in helping students to become aware of the problems where the curriculum focus is on examining the community problems and issues (Ornstien & Hunkins, 2014). The progressivism and reconstructionism of the philosophical foundation named as contemporary philosophy that set as the heart of designing the transdisciplinary curriculum that leads to transformative learning. Ornstien and Hunkins (2014) clarified the roles of the society and education; knowledge and learning; instruction; and purpose and programmes in the light of contemporary philosophy. In society and education, school improves society; learners' fulfillment; and independence and creativity, that are set as important factors. Education is concerned with social, moral, and cognitive terms where the focus is on the whole child. Values and beliefs are subjective based on the individual's view of the world. Regarding knowledge and learning, the emphasis is on students' interests where the subject matter is planned by teachers and students and focuses on solving real-life problems using integrated knowledge from different subjects. The instructions should vary to include the whole class, small groups, or individuals, where students are actively seeking information to use or apply. For the purpose and programmes, it is a mix of liberal art, practical, and vocational subjects where the curriculum is based on students' interests or needs that might have room for electives (Ornstien & Hunkins, 2014).

Philosophical foundation of the curriculum is considered to be at the root of considering many aspects while designing transdisciplinary curriculum using authentic assessment that lead to transformative learning. In addition, the assimilation stage of Piaget process which is

organizing curricula and teaching new experiences that are compatible with existing experiences considered to be the roots of designing the transdisciplinary curriculum using backward design. Biggs (1996) used this stage as basics for the constructive alignment theory that focus on the knowledge students should acquire and aligning it with the assessments.

The transdisciplinary curriculum is defined as the exploration of a contemporary issue requiring integration from multiple disciplines where knowledge and learning are connected and transferable to the real world (Lovering, 2012). Curriculum innovation has been defined as the implementation of a new curriculum that improves the educational system (Brundrett & Duncan, 2011; Karkkainen, 2012; Law & Li, 2013; Priestley, 2011). The transdisciplinary curriculum is a case of curriculum innovation as it involves complex integration to deliver quality learning experiences without neglecting academic outcomes (Tan & Leong, 2014). Ellis (2009) and Holley (2009) defined the difference between the types of integration, that are categorized as multidisciplinary, interdisciplinary, and transdisciplinary. The difference between them lies in the degree of integration within disciplines. They are discussed and compared with the Dugger and Fellow (2011) models of using STEM letters to show the degree of integration.

Multidisciplinary (S-T-E-M) is the lowest degree of integration between two or more disciplines that are placed side by side in solving problems where the topic is explained from the perspectives of multiple disciplines (Repko, 2008). It is known as correlated knowledge (Beane, 1991; Drake, 1991; Jacobs, 1989b; Scriven, 1994) while Wood (1997) referred to it as passive thematic. The interdisciplinary (SteM) depends mainly on the insight of the discipline where there is more integration between the subjects and the focus is on problem-solving where the knowledge is used and shared from different subjects in depth (Repko, 2008). It is the second stage of integration and known as shared knowledge due to the overlapping of concepts in active thematic units (Drake, 1991; Jacobs, 1989a; Romey, 1975; Scriven, 1994). Finally, the transdisciplinary (E→STM) is the strongest integration between knowledge where there is overlap between disciplines' boundaries that are integrated below one subject to represent a problem (Repko, 2008). It is known as reconstructed knowledge (Beane, 1991; Vars, 1991) and Dewey (1986) promoted the term core curriculum as the reconstruction of knowledge.

Many researchers emphasize that learning requires active mental processes that allow for connection between knowledge, ideas, repetition, practice, and memorization (Gettings, 2016; Gross &Gross, 2016; Howe, 1998; Liao, 2016; Steyn, 2017; Strange & Gibson, 2017). Therefore, effective learning should involve the transformation and reproducing of new materials. McTighe and Wiggins (1999) emphasized that transformative learning moves

students from knowing to being able to do. The emphasis is on using multiple knowledge strands to solve problems in real-life contexts, and assessments should be diagnosing students' abilities and progress toward achieving real-world abilities (Fook & Sidu, 2013). Educational experts pointed out that integration between disciplines allows for more concepts that can be taught in less time and at higher levels (Drake & Reid, 2010; Jacobs, 1989). There are several benefits of using integration between disciplines in the curriculum: coherence of concept development; breadth and depth of knowledge; differentiation; motivation; brain development; enhanced sense of community; overall achievement; and perspective transformation of viewing the world (Michigan Department of Education, 2014).

Drake & Reid (2010) emphasized that the integrated curriculum is reducing the stress of teaching multiple expectations and in addition that teachers will find an increase in students' engagement and decrease in attendance and behaviour problems. Susan Drake's model is best achieved when teachers work collaboratively with other teachers and sometimes students (Leopone, 2016). Drake's model (Know, Do, and Be - KDB) emphasized the backward design to be used in designing curriculum where the desired outcomes, instructions and assessments are constructively aligned. Know lies in the core concepts and big idea; Do is the 21st century skills; and Be is the attitudes and beliefs (Drake, 2007). Drake's model requires collaboration from teachers to design and plan for integrated curriculum, assessment, and instructional activities (Drake & Burns, 2004). The process of Drake's step-by-step planning is started first by reading the curriculum document vertically (two grades below and one up) and horizontally (expectations across subjects) to get an idea about the main concept initially around KDB. Then choose an appropriate theme, brainstorm activities using a concept web and finalize KDB. The next step is to create rich assessment that incorporates the KDB and curriculum expectations. Create two to three big questions and zoom in on certain curriculum expectations that do not fit in the unit and include them in daily lessons. Finally, create daily instructional activities that reflect the big questions where students can achieve the KDB. Results from Leopone (2016) about teaching an integrated curriculum using Drake's model stated that collaboration between teachers improved and new strategies were shared among them; however, some teachers found difficulty in teaching specific mathematics concepts, and others reported that small concepts have been covered by conveying bigger ideas.

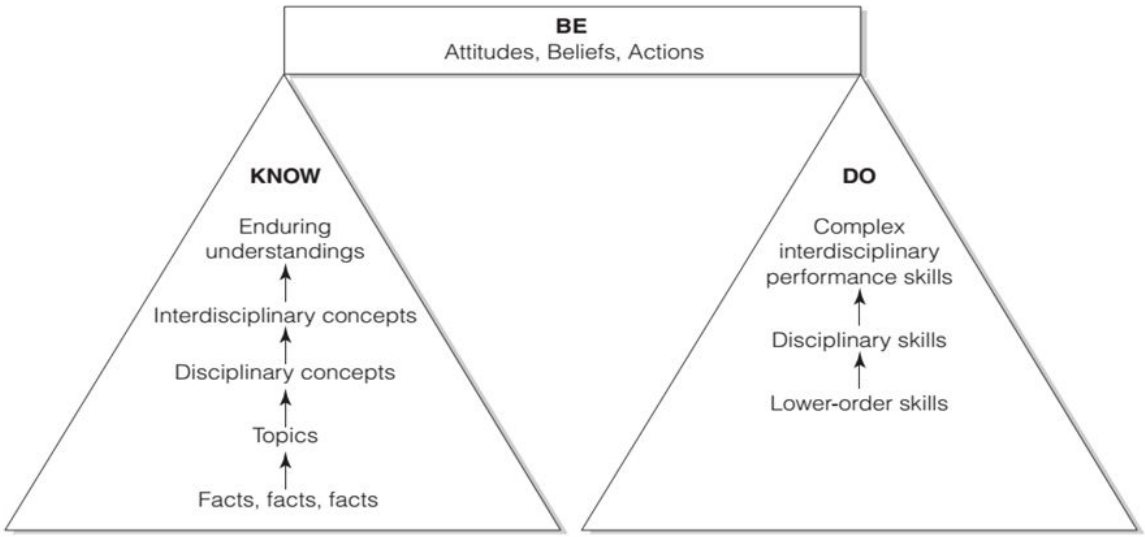

Figure (2.2): Drake's model of designing an integrated curriculum (Drake & Burns, 2004, p.50).

Beane's approach to the integrated curriculum differs from Drake's in the way of designing the higher level of integrated curriculum that focuses on students' interests (1991). Beane focuses on the intermediate age of students (middle school) as they are involved in planning the integrated curriculum based on their interests (Lepone, 2016). Beane believed that information should not be taught separately while all real-world problems are not separate information which will give students the effort of trying to connect this information (Lepone, 2016). Beane (1991) emphasized that the curriculum integration approach rests on two underlying assumptions: first, to use students' curiosity in planning transdisciplinary curriculum is the best approach to increase students' engagement and eliminate behavioural problems; second, meaningful learning occurs when students try to solve questions they posed based on their interests. He criticized the interdisciplinary approach and highly emphasized the transdisciplinary as the probability of separate subjects does not exist (Lepone, 2016). Three considerations should be kept in mind while planning a transdisciplinary curriculum in order to form authentic learning: provide general information to students, serve them, and perceive students as young adults (Lepone, 2016). Beane's approach emphasizes giving students a list of questions about themselves and the world, then working together to find commonalities between them. After that, students work together to identify a theme that links between the personal and world through the questions chosen. Finally, students plan the unit, assessment tools and activities with the teacher. Great emphasis has been put on careful curriculum planning that will draw heavily on a variety of disciplines (Beane, 1995). Beane's model is not easy to grasp, represents a new way of thinking, and is the most effective way to transmit

knowledge and make learning relevant and retainable (Lepone, 2016). In this model of curriculum, students become more self-directed learners, however, his model was limited to the middle school students (Lepone, 2016). In conclusion, Drake and Beane have different approaches: Drake heavily relies on teachers and curriculum expectations that are viewed as interdisciplinary, while Beane's approach is viewed to be transdisciplinary as he relies more on students' interests and leading their learning starting from the design of the theme (Ontario Ministry of Education, 2006). However, both models promote students' engagement, retention of knowledge, and the development of 21st century skills (Lepone, 2016).

The integrated curriculum gives learners the opportunity to apply multiple types of intelligence and higher-order thinking within the context of authentic and performance assessment that lead to transformation (Drake, 2007; Hartzler, 2000; Jacobs, 1989). An integrated curriculum enhances critical thinking and problem-solving due to the interchange between the breadth and depth of integrated knowledge within disciplines (Jacobs, 1989; Wiggins & McTighe, 2005). It is important to note that the curriculum integration is the teachers' responsibility as well as that the degree of integration between disciplines is at the discretion of teachers (Lepone, 2016). Teachers must have an awareness of holistic education in order to apply this approach (Gerber, 2001). Boyd (2004) stated that the interrelation and connection established between integrated knowledge is one of the powerful techniques for students to acquire information and keep it in their long-term memory to utilize it in other situations. Accordingly, students are not only able to connect and integrate information to their points of reference but also, their abilities to gain information are increased (Lepone, 2016). Sorel (2005) pointed out that the world is not divided into scientific issues and social issues; on the contrary individuals are in constant interaction with the world around them. The more students are exposed to connections between planets, people, and issues that are interconnected, they start to make connections themselves (Lepone, 2016). The integrated curriculum allows students to reinforce their skills of one subject through using them in other subjects (Arslan & Saka, 2010). The integrated curriculum is shown to increase students' interpersonal skills, allow for deep differentiation, and encourage holistic thinking and connection to real life (Lepone, 2016). It has been found that students who are involved in planning and developing their integrated lessons, themes, activities, and assessments based on their interests are more likely to be engaged in global issues discussion with a higher level of sophistication (Brown, 2002; Lepone, 2016). As a result, the integrated curriculum is not only benefiting teachers but is also benefiting students and developing strong relationships between them (Lepone, 2016).

Lepone (2016) stated that the most important benefits students gain from an integrated curriculum is the knowledge retention where they remember information and are able to utilize it in new situations. Beane (1991) emphasized the knowledge retention when they are involved and interact with the environment and what they experience becomes in their system of meaning. The student-centred approach in the integrated curriculum is essential for students to internalize information, create meaning for it and demonstrate retention (Beane, 1991; Drake & Reid, 2010; Ramsburg & Youmans, 2013). Retention of knowledge doesn't mean that students go in rote of memorization, in fact they will be likely to forgot it and lose information from their working memory if it is not linked to a large and meaningful concept (Lepone, 2016). On the contrary, students learn and retain information easily when it can be applied to their own contextual frame of reference by personalizing information that allows them to understand the significance of information and apply it into new contexts (Lepone, 2016). In order for students to retain information easily, they must be involved in learning where they can think critically, reflect on their learning, be creative and innovative, self-directed learners, communicate and collaborate with their peers (ElSayary, Forawi & Mansour, 2015; Lepone, 2016). Drake and Burns (2004) proposed categories of integration and the primary assessment concern for each category. Interestingly, Drake was concerned that the primary assessment of the transdisciplinary is the authentic assessment.

Approach	Definition or Description	Characteristics	Primary Assessment Concern	Features Equivalent Across All Inter-disciplinary Approaches
Fusion	Something is fused to an already existing curriculum. Infusion of a content area, thinking skills, arts techniques, etc., would mean these were taught within every class.	A focus that is embedded into all school life.	Subject specific	Mapping backwards design—using standards Exemplary teaching/ learning strategies
Multidisciplinary	*Multidisciplinary* approach is additive, not integrative. The disciplinary perspectives are not changed, only contrasted. Team-taught courses in which faculty provide serial lectures are often multidisciplinary.	A focus on the concepts and skills of each of the disciplines independent of the others.	Disciplinary concepts and skills	Set in student-relevant real-world context as much as possible Performance demonstrations as well as standardized assessment
Interdisciplinary	*Interdisciplinary* is when students and instructors come together to analyze differences in disciplinary approaches to a problem and to work toward a synthesis resulting in a new, more comprehensive view than allowed by the vision of any one field.	A focus on common concepts and skills across the disciplines	Common concepts and skills across the disciplines	
Transdisciplinary	*Transdisciplinary* approaches provide holistic schemes that subordinate disciplines, looking at the dynamics of whole systems (i.e., place-based education).	Real world context and student questions; life skills	Authentic assessment in a real life context	

Figure (2.3): Drake's categories of integration types (Drake & Burns, 2004).

The integrated curriculum has received criticism from many researchers. Teachers were feeling isolated while planning this curriculum where they were not familiar with the models of integration and the framework to use that requires collaboration between different disciplines (Hood & MacMillan, 2002). Another criticism was about integrated curriculum implementation where teachers and administrators couldn't recognize the quantity and quality of learning that could take place (Russell & Burton, 2000). In addition, Dawson (2003) found that teachers' focus and higher priority is to produce higher test scores which distrust the use of integrated curriculum. Beane (1995) emphasized the use of the higher level of integrated curriculum, "transdisciplinary", where it will be a loss for subject teachers but will be high

benefit for students' learning. Beane's critics claim that the full teaching of an integrated curriculum will not allow teachers to cover their subject curriculum. Beane's response was in alignment with Dewey, Whitehead and Gardner where they all believe in teaching a lower amount of meaningful information but in more depth based on students' interests (Lepone, 2016).

Capraro et al. (2013) described the strong relationship between STEM subjects as they complete each other using parts of the body where science is the musculoskeletal system: technology is a tool which is the hand; engineering is the way of thinking (brain); and mathematics is the heart and blood that moves around the body. Science is seeking consistency and understanding of the world (NRC, 1996). Technology is an applied science, it is human-made and driven by people who can produce new products that are useful (Yakman, 2010). Engineering is the design process that uses and applies information from other disciplines to be utilized economically and benefit society (Mello, DiaBiasio & Vaz, 2008). Mathematics is the logic that investigates the patterns and relationships of sciences (Delvin, 1997).

Adding "A" to STEM is sparking the interplay between convergent and divergent thinking (Yakman, 2008). Yakman suggested a framework that is used in teaching STEAM, stating that art is the subject that promotes students' creativity. The term 'art' is used for: Design Art, Language, Sociology, Philosophy, Psychology and History (Yakman, 2008). The focus of this study will be on the Language Art and Design Art. The shift from STEM to STEAM allows students to think divergently where each creates a different product based on their points of view (Madden et al., 2013). Corply (2015) stated that there are three elements that promote students' creativity: integrated courses, problems, or projects; positive encouragement and feedback; and rewarding for completing a task.

Each discipline in STEAM has different processes, practices, and requirements. The innovation in science is the hands-on; technology is the projects; engineering is the design planning; art is the creative products; and mathematics is the prominent use of modelling (Drake, 2007; France et al., 2011; Howes et al., 2013). In addition, understanding how science works in technology and society is the starting point of many curricular and assessment innovations (Lee & Roth, 2011). The rationale that influences our vision of the world is basically enhanced from STEAM disciplines (Drake, 2007; Howes et al., 2013). Science usually models real-life phenomena in certain ways that enable predictions to be made. Sustainability is a significant concept for design and technology. Engineering is providing authentic tasks for other disciplines. Producing creative products is influenced by art. Finally, success relies on our vision of viewing the world mathematically, analytically, and rationally

(Drake, 2007; Howes et al., 2013). In addition, integrating creative writing, visual and performing art enhance students' achievement in other subjects (Drake, 2007; Jacobs, 1989).

Furthermore, both skills and content learning are supported by the application of skills from the process-oriented to different disciplines that are integrated together (Hartzler, 2000). The arts practices are a starting point of transformational practices of teaching and learning where teachers use the artistic component as an assessment task to demonstrate students' understanding of reading elements, science concepts, engineering and technology problems, and mathematical concepts (Peel, 2014). It is important to note that the artistic process allow students to change their habits of mind while solving problems using different disciplines (Peel, 2014; Yakman, 2008). Integrating mathematics within all other disciplines allows students to change their perspectives when using mathematical laws in learning about society (Hickman, 1992). Guzey et al. (2016) strongly promoted engineering habits of mind as general principles of engineering education that are mentioned in National Research Council (NRC), 2009. The STEAM curriculum design intertwines the science, technology, engineering, art, and maths in conducting research and integrating complex sets of information (Keane & Keane, 2016). The transdisciplinary STEAM allows for utilizing existing and new tools in order to represent real-world practices (Standford, 2014). The design of transdisciplinary SETAM mixes activities integral to imagining the unknown with the known, using technology as a tool, assesses data and probability, and engineers related solutions for testing and evaluating (Keane & Keane, 2016).

Art and STEM make use of each other's processes as the interplay between art knowledge and STEM knowledge highlights results when both inform investigations and propositioning (Keane & Keane, 2016). As art and STEM both focus on convergent study of process, also they are focusing on divergent study of relationships across disciplines (Keane & Keane, 2016). In fact, art and science are complimentary disciplines as experts usually see STEM and art having opposite characteristics (Sousa & Pilecki, 2013). This integration opens linear thinking of unexpected innovation (Keane & Keane, 2016). The STEAM curriculum design provides opportunities that transform traditional instruction in separate classes into transdisciplinary practices in integrated classes (Keane & Keane, 2016). STEM creates an objective view of the world while art creates a subjective view of the world. STEM subjects tend to be logical, analytical, reproducible, and useful, while arts tend to be intuitive, sensual, unique, and frivolous (Sousa & Pilecki, 2013). Individuals' brains need both in order to make suitable and appropriate decisions. Art subjects were lost in schools where the focus was on reading and mathematics (Parsad & Spiegelman, 2012). The arts subjects have a power that

makes scientists, mathematicians, and engineers use artistic skills borrowed from arts as scientific tools to include them in the following abilities: draw on curiosity; observe accurately; perceive an object in a different form; construct meaning and express one's observations; work effectively with others; think spatially; and perceive kinesthetically (Sousa & Pilecki, 2013). There are different parts of the brain that are used with different subjects of arts (Sousa & Pilecki, 2013). For music, the auditory cortex usually responds to the musical tones. For dance, a portion of cerebrum and most of the cerebellum responds to all kinds of movements while dancing. For drama, the limbic system that is known as the emotional control centre and areas of the cerebrum focus on spoken language to provide the emotional component. For visual art, the internal visual cortex can recall reality or create fantasy with the same ease. Finally, the prefrontal cortex is the control area that coordinates all this information to help individuals make the suitable decision (Sousa & Pilecki, 2013).

Arts play an important role in developing learners' cognitive, emotional and psychomotor pathways in the brain (Sousa & Pilecki, 2013) which enhance the emancipatory, communicative, and instrumental learning that lead to transformational learning (Liao, 2016; Peel, 2014). In addition, the arts disciplines develop students' 21st century skills that include: creativity, problem-solving, communication, collaboration, self-direction, and innovation skills (Peel, 2014; Sousa & Pilecki, 2013; Yakman, 2008). The major reasons of integrating art are represented in the figure below and described in detail.

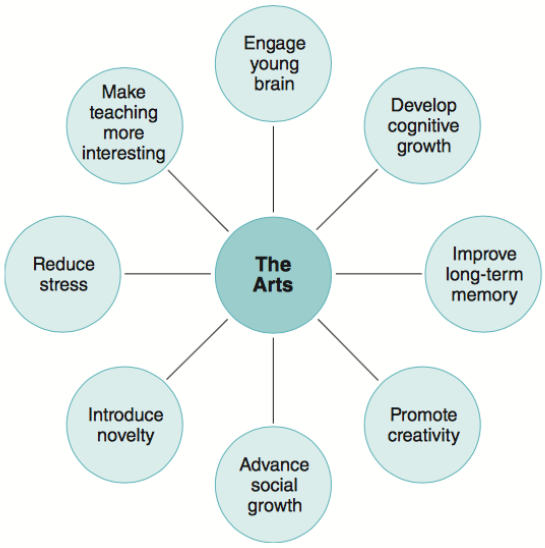

Figure (2.4): The reasons for art to be available to all students (Sousa & Pilecki, 2013, p. 16).

Art engages young brains where cognitive and visual-spatial areas are developed as the students learn songs and create drawings and paintings, while music helps young learners to remember information (Eisner, 2002b).

Furthermore, the arts develop cognitive growth and competencies that benefit students in their learning and prepare them for the skills demands of the 21st century. Eisner (2002a) identified the eight competencies of art as the following: first, perception of relationships where students recognize that each part of work influences each other part. The same skill also helps biologist recognize for example how the shift from a part in an ecosystem can affect other parts of that system. Second, an attention to note where students recognize that small differences in arts can have great effects. This is similar in writing where great attention to the use of language is needed to employ allusion, innuendo, and metaphor. The same applies to scientists who are trying to explain complex concepts to nonscientists. Third, the divergence in thinking where problems can have more than one solution and the question may have more than one answer. Similar skill is practiced in STEM subjects where many problems can be solved in different ways. Fourth, the ability to shift goals in process where art help learners to see the relationships that leads to a shift ends in the process. Fifth, the permission to make decisions in the absence of the rules where personal judgments take place in assessing what feels right to decide when a task is well done. Sixth, the use of imagination as a source of content where the use of the mind's eye is important to determine the appropriate plan to follow. Seventh, the acceptance of operating within constraints by inventing ways that manipulate to these constraints. Eighth, the ability to see and frame the world from an aesthetic perspective.

Arts help in improving students' long-term memory (Sousa & Pilecki, 2013). Memory is the storage of information that is considered to be the input. The information usually passes through three different stages. The first stage is the short-term memory where the information is kept for a short time. Information then goes to the next stage which is called the working memory, otherwise it will be lost. The working memory is the active process that works on rehearsing information visually, auditory and kinesthetically in order to transfer it to long-term memory. The working memory is the stage of differentiating instructions and allows students to do two tasks together if one of them requires less attention than the other. The information then transferred to long-term memory lasts for a long time after good rehearsing through appropriate teaching strategies (Long et al., 2011).

Integrating arts into STEM subjects allows information to be transferred into long-term memory (Sousa & Pilecki, 2013). A study of integrating arts stated that retention of learning has been improved significantly through eight effects: rehearsing the information and skills;

elaborating that adds meaning to learning; generating more information; instrumentally using the materials; students verbally communicating their learning; students are contributing to establish meaning; the degree of emotional arousal over learning; and representation of learning visually through pictures (Rinne, Gregory, Yarmolinskaya & Hardiman, 2011). Many complaints have been raised from STEM teachers that students do not recall much information of what they have learned which means that information was not encoded in the long-term memory but was received in the working memory and then faded away (Sousa & Pilecki, 2013).

Integrating art into STEM subjects promotes creativity where, as Csikszentmihalyi (1999) mentioned, that creativity is the interaction between fields, domains and learners. In addition, Corply (2015) mentioned three elements that enhance students' creativity, through learning integrated courses, problems or projects; positive encouragement for students who are engaged in creative tasks; and rewarding students for producing creative products. Furthermore, Sternberg (2007) stated twelve strategies that are used to transform students' learning and drive the habits of creativity. These strategies are: involving students in open-ended tasks and expecting the unexpected from them; encouraging students to ask questions based on their interests and try to solve them divergently; generating and communicating ideas with their peers; connecting knowledge from different disciplines; challenging students to increase their intrinsic motivation in completing their tasks effectively; self-assess their work and reflect on their learning; providing them with ill-structured problems; that students should lead their learning based on their interests; using different ways of authentic assessment; pushing them to the extent of their ability and within their comfort zone; build students' self-efficacy by raising metacognitive awareness; and teachers need to act as role models for their students.

Kaufman and Beghetto (2009) proposed a framework for creativity known as the 4C model that enables people to understand the scale used to measure creativity. The creativity model is classified as Mini-c, Little-c, Pro-c, and Big-c, mentioned in the figure below. Creativity was known before as Little-c and Big-c, then Kaufman and Beghetto (2007) suggested new categories of creativity which are Mini-c and Pro-c due to the gap that occurred between the Little-c and Big-c. The Little-c is known as everyday activities while Big-c represents the highest level of creativity, and people rarely can reach this level. The Little-c creativity needs three variables in order to occur: domain-relevant skills, creativity-relevant skills, and task motivation, where the domain-relevant skills include knowledge, technical skills, and specialized talent (Amabile, 1996). Mini-c creativity is suggested to be the first level

and is aligned with the Vygotskian conception of cognitive and creative development which argues that all learners have the potential and basics for being creative where the starting point is a transformation of students' mental structures based on their characteristics and existing knowledge (Moran & John-Steiner, 2003).

The 4C model is aligned with the transdisciplinary STEAM in transforming students' learning where the figure below shows the transition from one level to another. The first level is the mini-c creativity; all individuals start from this level and a change in their perceptions and habits of mind occurs to shift to the next level of creativity. Rarely students can jump from Mini-c to Pro-c level of creativity however some will go through formal apprenticeships that will lead to Pro-c which is done through academic institutions. Another path is the tinkering which is to develop students' creativity in a domain and improving even without mentoring. The tinkering then moves to the little-c creativity where emancipatory, communicative, and instrumental learning takes place to prepare students to reach the next level of creativity. The third level (Pro-c) is where the shift to it is done through informal apprenticeship by peer mentoring or a more experienced mentor. This is the stage where individuals make their talents fertile in their professional life. Accordingly, the right choices of students in their careers should be taken. Another path is considered to be the end destination of reflection. Not everyone has the desire of developing creativity at the professional level. In contrast, some individuals use their creativity in expressing themselves, sorting out emotions, or exploring ideas and life experiences. In pro-c creativity there are two paths, one path where individuals remain creative in this level and fertile in their professional lives. Other people may go through another path where they reach the highest peak of creativity (greatness) and subsequently progress to reach to the Big-c. Kaufman and Beghetto (2009) emphasized the important role of authentic assessment in developing students' creativity and transforming their learning.

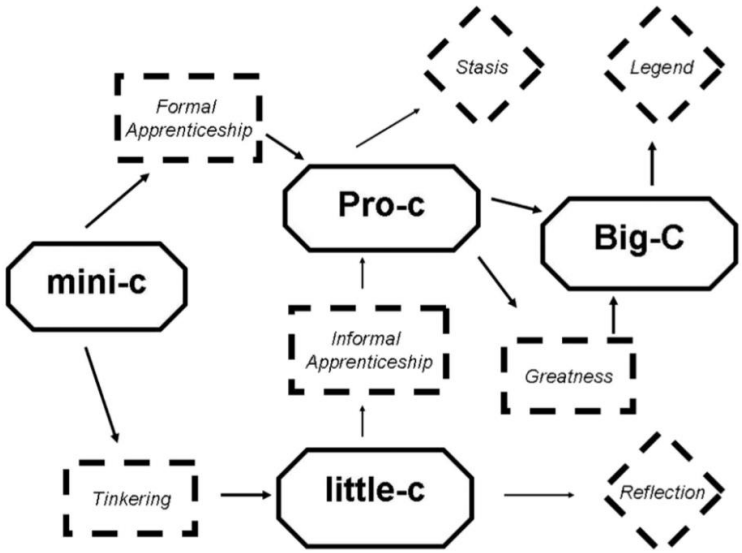

Figure (2.5): The four-C Model of Creativity (Kaufman & Beghetto, 2009, p.7).

Another reason for integrating art to STEM is that it advances social growth in term of counterbalancing the antisocial and anti-collaborative nature of today's technology (Sousa & Pilecki, 2013). Technology integration within STEAM subjects should be used as a tool that serves in the learning process (ElSayary, Forawi & Mansour, 2015) and not to replace the social interaction between students to be done electronically (Sousa &Pilecki, 2013). Technology use within teaching and learning activities has transformed the nature of instruction, however art integration requires collaboration between students in solving problems and generating new ideas (Dokoupil, 2012). The social relationship between students is important for the human development and behaviour as the cerebral neurons of the brain are dedicated to processing social interactions (Chen, 2009).

One of the benefits behind integrating art within STEM subjects is to introduce instructions novelty (Heimann, Tjus & Strid, 2010). In order to expect the unexpected from students, they should receive their instructions from teachers in an unexpected way that makes their brains explore the nature of attention through three different systems: altering, orienting, and deciding (Sousa & Pilecki, 2013). The first system is the altering where students' brains monitor the environment for any unusual activity or emotion that is introduced by their teachers. The second system is the orienting where the brains are facing the source of alert which is the unusual activity introduced by their teachers. The third system is the executive control where decisions should be taken based on teachers' introduction of the unusual activity and this is the job of the frontal lobe of the brain.

In addition, integrating art within STEM subjects is reducing stress where creating an artistic product can be a pleasurable experience (Toyoshima, Fukui & Kuda, 2011). In other

words, integrating arts can enhance students' learning in other STEM subjects, and it is not only for students who want to be artists (Sousa & Pilecki, 2013). In addition, adding art to STEM increase females' interests toward scientific subjects (Gettings, 2017; Gidcumb, 2016; Liao, 2016). It was stated that teachers who are focusing on gender equality while planning for curriculum instructions are more likely to influence males' and females' interests toward STEAM subjects (UNESCO, 2017). Interestingly important to note that there are no biological differences between males and females in their tendency toward scientific subjects and females were less interested in scientific subjects, due to the influence from the society who review scientific fields to be for males (Gidcumb, 2016). On the other side, integrating art makes teaching more interesting for STEM teachers that leads to job satisfaction where planning and instructions become more creative (MetLife, 2012). Integrating art also makes the lessons more successful and interesting for both teachers and students where developing creative thinking takes place in their classrooms (Ingersoll, Merrill & May, 2012).

The criteria of deciding what makes a good piece of art are quite different from what makes good science, technology, engineering or mathematics (Sousa &Pilecki, 2013). However, teachers who are aware of the area of intersection between art and STEM learning can easily demonstrate to their students the distinction between these domains during activities. On the contrary, Leonardo da Vinci and Michelangelo Buonarroti did not see boundaries between these subjects (Sousa & Pilecki, 2013). For example, "Da Vinci conceptualized the helicopter and battle tank and made important discoveries in anatomy, hydrodynamics, and optics" (Sousa & Pilecki, 2013, p. 31). Michelangelo was an artist who "works as an architect and engineer, designing the large dome of St. Peter's Basilica in Rome" (Sousa & Pilecki, 2013, p.13).

The NRC (2012) framework involves three dimensions: scientific and engineering practices, crosscutting concepts and disciplinary core ideas. STEAM has gained further momentum as the framework has been adopted through Next Generation Science Standards (NGSS) (Keane & Keane, 2016). The disciplinary core ideas represent specific content of physical, life, earth and space sciences as well as engineering and technology. The scientific and engineering practices and crosscutting concepts deal with learning certain skills and concepts. The crosscutting concepts shed the light on the knowledge, language, and skills that are shared by the arts and STEM where there are new opportunities for fostering innovative thinking through transdisciplinary learning. Research shows that students who are exposed to arts instruction are most likely to perform better and acquire these STEM related skills and concepts (Sousa &Pilecki, 2013). The figure below shows a comparison between the first two

dimensions of the NRC framework with the cognitive, emotional, and physical skills (emancipatory, communicative, and instrumental learning) that students acquire while participating in art- related instructions (Sousa & Pilecki, 2013).

First Two Dimensions of National Research Council Framework	**Skills Acquired in Arts-Related Instruction**
Scientific and Engineering Practices: 1. Asking questions and defining problems 2. Developing and using models 3. Planning and carrying out investigations 4. Analyzing and interpreting data 5. Using mathematics and computational thinking 6. Constructing explanations and designing solutions 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information	*Instrumental and Vocal Music, Art, and Dance Instruction:* 1. Exploring the various ways to create art and make an informed decision 2. Researching and appreciating the work of other artists, such as an analysis of a Beethoven sonata 3. Making colour choices for a mural based on other works, as well as applying understanding of colour and colour variations. 4. Researching a written work, such as *Romeo and Juliet*, and creating a ballet interpreting the work 5. Creating a series of pottery measuring cups, calculating the amount of clay, and the amount of kiln-shrinkage to have exact proportions 6. Writing a script based on a current events issue 7. Having a team create a comic strip in a roundtable format, based on a current political situation 8. Creating a puppet show based on the "greenhouse theories".
Crosscutting Concepts: 1. Patterns 2. Cause and effect; mechanism and explanation 3. Scale, proportion, and quantity 4. Systems and system models 5. Energy and matter: flows, cycles, and conservation 6. Structure and function 7. Stability and change	1. Discussing and performing rhythmic and melodic musical patterns 2. Experimenting with different media in creating a work of art on paper: water colour vs. acrylics vs. chalk vs. pencil 3. Creating a sculpture 4. Analyzing the orchestration of a symphony both by visual review of the score and listening cues 5. Choreographing a piece depicting reclamation of western Pennsylvania steel mill buildings and land 6. Creating a set for a stage production 7. Analyzing and listening to the history of jazz in America

Table (2.1): Practices and concepts from the k –12 National Research Council Framework and skills acquired in arts-related instruction (Sousa & Pilecki, 2013, p.33).

The hidden curriculum is what has been taught and not planned for (Ornstien & Hunkins, 2014). The hidden curriculum with STEAM is the habits of mind that are known as

dispositions that include skills and the inclination to use them (Gettings, 2017). Gettings (2017) pointed out eight dispositions or habits of mind "develop craft, engage and persist, envision, express, observe, reflect, stretch & explore, understand arts community". Develop craft is to learn how to use tools, materials, artistic conventions and learn how to care for those tools, materials and space. Engage and persist is to learn how to deal with problems of relevance within the art world and to develop focus conducive to working and persevering at tasks. Envision is to learn how to imagine things that cannot be observed directly and imagine the possible next steps. Express is to learn how to create works that represent an idea, a feeling, or a personal meaning. Observe is to learn how to look carefully in depth for things that might not be seen ordinarily. Reflect is to learn how to think and communicate with others in judging one's work and/or others' work. Stretch and explore is to reach beyond one's capacity and embrace learning from mistakes in addition to transferring what they have learned into new situations. Understanding the arts community is to learn how to act as an artist with other professional artists.

In order to transform students' habits of mind and change their perceptions of viewing the world, there are some sets of actions and goals that should be considered while developing the curriculum (Gettings, 2017). These goals are to engage students in real-world problems that integrate and blend STEAM disciplines and allow students to envision divergent possible solutions that are related to challenge; to use artistic thinking skills and applications to stretch beyond the students' visions before, during and after the work is done. Another goal is to solve challenging problems with originality, fluency and imagination. Select and use art media, subject matter and symbols for expression and communication. Students should use materials, methods, technology and information in a creative manner within the design process. Students should observe and reflect during the work process and be open to new suggestions and opinions. They should develop understanding of roles and careers in addition to the awareness of royalty and copyright requirements. Finally, they should be able to demonstrate the benefit of the use of artistic design on their end products. These goals are part of an authentic assessment process where students experience learning through the emancipatory, communicative and instrumental learning (Gettings, 2017). The STEAM curriculum is not like the STEM curriculum as STEAM uses a wider variety of habits of mind through the strong integration that occurs between subjects and skills (Gettings, 2017). It can be used as a tool that leads to transform students' learning (Gettings, 2017).

There is another view emphasizing that integrating art to STEM is to be viewed as a transdisciplinary curriculum where the focus is applications to social practices (Guyotte,

Sochacka, Costantino, Walther & Kellam, 2014; Liao, 2016). Integrated STEAM education is a transdisciplinary curriculum that focuses on transformative learning experiences (Liao, 2016). Art is considered to be the vehicle for learning STEM in terms of transforming students' learning (Liao, 2016). Determining the best transdisciplinary lessons is by observing students who are engaged, reflect, explain the findings of their work, and are able to transfer it to new concepts (Gettings, 2017; Liao, 2016; Taylor, 2017). In order to achieve the goal of creating transformative learning, innovation should be directed toward the creation of transdisciplinary STEAM curricula that address social and global issues (Liao, 2016; Turner, 2015).

2.4 Authentic Assessment

Lev Vygotsky's theory is not only focusing on cognitive theory but also on the socio-cultural development (Bruner, 1990). Furthermore, Bass (2014) mentioned that the authentic assessment tasks are considered to be social cognitive pedagogies that engage learners in procedural learning process. Many researchers mention that the transformation in students' learning comes from the change in assessment methods where the feedback given to students influences their lives and careers (Brown, Bull and Pendlebury, 1997; Race, Brown and Smith, 2005). Koh, Tan, and Ng (2012) focused in their study on engaged learning that lies in the shift from conventional assessment to authentic assessment. Authentic assessments are another form of formative assessment where students perform tasks rather than selecting answers (Lichfield & Dempsey, 2015) such as learning logs, projects, inquiry-based and problem-based tasks that are used also for assessing creativity and possess the characteristic of meaningful learning (Cheng, 2015; Silveira, 2013; Synder, 2013). It allows for flexibility, openness, and differentiation of students' learning as they can learn different things based on their interests (Elton, 2010) and promote their competencies in a real-world context with many unknowns and uncertainties (Cheng, 2015). Assessment should be related to what they are learning (Biggs & Tang, 2007) as well as the relation to the career goals and practices through problem-solving (Lichfield & Dempsey, 2015). The most prevalent misconception is that once teaching is finished, learning is done as students have acquired the content knowledge. However, after students acquire the content knowledge they should use it in solving problems, creating, revising, revisiting, and engaging in the process through carefully constructed and relevant authentic assessment (Lichfield & Dempsey, 2015). These assessments allow students to reflect and get feedback that focuses on self-improvement and personal goals that are inherent in the cognitive process (Beghetto, 2005; Beghetto and Kaufman, 2010; Black and William,

2006; Brookhart, 2010). Teachers should guide students and leave the learning outcomes open-ended, to accommodate and expect the unexpected unique products that encourage creativity (Cheng, 2015; Earl, 2013).

Authentic assessment promotes students' metacognition as a key to learning (Azim & Khan, 2012) and develops students' higher-order thinking skills (Koh, Tan & Ng, 2012). Meyers and Nulty (2009) mentioned the main principles of the meaningful course. First, using constructive, sequential and integrated knowledge is to be applied in authentic, relevant and real-world applications. Second, students should be engaged in higher-order cognitive processes that provide challenge, interest and motivation to learn. Finally, in the integrated curriculum, the way students learn and solve problems should be aligned with the ways students are assessed authentically. Accordingly, these assessments facilitate the synthesis of interdisciplinary knowledge (Fournier et al., 2011) and the transformation of learning (Barnett & Ceci, 2005). The authentic assessments allow students to have several checking points to reflect on their work which make learning more meaningful (Barnett &Ceci, 2005). Litchfield and Dempsey (2015) suggested the shift of time allocation from designing the traditional way of formative assessment to include authentic assessment, as mentioned in the figure below.

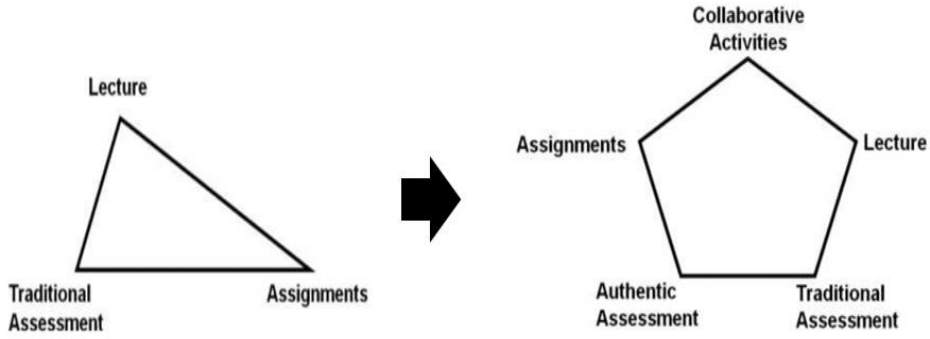

Figure (2.6): Shift in the time allocation from traditional assessment to include authentic assessment (Litchfield and Dempsey, 2015).

The Learning and Teaching Center of Lombardi (2008) mentioned the difference between the traditional assessment and authentic assessment. It is stated that traditional assessment, which lies in selecting responses, contriving content, recalling and recognition of information, is teacher-structured and has indirect evidence, while authentic assessment lies in performing a task, deals with real-life applications, requires construction and applying knowledge from different disciplines, is student-centred and has direct evidence.

Earl (2003) stated that the assessment must be an integral part of the learning process that stimulates further learning. Interestingly, the word "assessment" is derived for the Latin

"assidere" which means "to sit beside or with" (Wiggins, 1993). There are three main approaches for assessment: assessment *of* learning; assessment *for* learning; and assessment *as* learning. All of them are essential and should be understood very well for teachers in order to know how to use each one. Teachers' roles and goals of assessment differ according to the needs (Earl, 2003). The table below shows the assessment roles and goals stated by Wilson (1996) and adapted by Earl (2003).

Role	**Goal**
Teacher as mentor	Provide feedback and support to each student.
Teacher as guide	Gather diagnostic information to lead the group through the work at hand.
Teacher the accountant	Maintain records of students' progress and achievement.
Teacher as reporter	Report to parents, students, and the school administration about student progress and achievement.
Teacher as programme director	Make adjustments and revisions to instructional practices.

Table (2.2): Assessment roles and goals adapted from Wilson (1996) and stated by Earl (2003).

Assessment *of* learning is the kind of assessment that is usually done at the end of term or year. This assessment comes in grading and is reported to students with numbers and without feedback given to them (Earl, 2003). The information given from the assessment of learning gives teachers, managers, parents and students a summary about students' progress (Mutch, 2012). The purpose of this assessment is the accountability (Mutch, 2012).

Assessment *for* learning is shifting the emphasis from summative to formative assessment that is used to inform instructional activities. This type of assessment enhances learning (Earl, 2003). It happens in the middle of learning more than once and provides students with feedback to improve their learning (Earl, 2003). The assessment *for* learning is providing students and teachers information to be used as feedback to modify teaching and learning activities (Mutch, 2012). The purpose of this assessment is improvement (Mutch, 2012).

The assessment *as* learning is emphasizing the role of students in formative assessments (Earl, 2003). Students are actively engaged and critical assessors where they can make sense of their knowledge, relate it to prior knowledge, transfer it to new situations, and master the

skills involved (Earl, 2003; Mutch, 2012). These are a process of metacognition where self-assessment is at the heart of the matter. Students here monitor what they are learning and use the feedback to improve their work (Earl, 2003). This effective assessment empowers students to ask reflective questions and consider a range of strategies for learning (Earl, 2003). Students decide with their teachers the important evidence they can keep and organize (Earl, 2003). The three approaches contribute to students' learning in vastly different ways (Earl, 2003). The table below shows the differences between them.

Approach	Purpose	Reference Points	Key Assessor
Assessment of Learning	Judgments about placement, promotion, credentials, etc.	Other students	Teacher
Assessment for Learning	Information for teachers' instructional decisions	External standards or expectations	Teacher
Assessment as Learning	Self-monitoring and self-correction or adjustment	Personal goals and external standards	Student

Table (2.3): Features of Assessment of, for, and as, Learning (Earl, 2003, p. 6).

Earl (2003) shows the shift from the traditional way of assessment where the focus was on assessment of learning to the extent that there is no space for any other types of assessments, to the reconfigured model of assessments where the focus is on the assessment as learning. The figure below shows the shift from the traditional assessment model to the reconfigured assessment model with a suggested different type of balance.

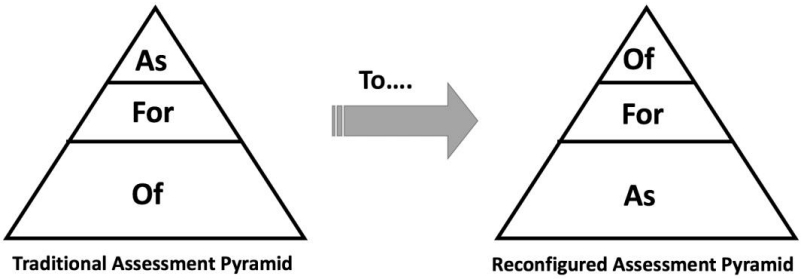

Figure (2.7): Shifting the balance of traditional assessment model to reconfigured assessment model (Earl, 2003).

Based on Almqvist, Vinage, Vakeva & Zanden (2017), the authentic assessment is considered to be a kind of assessment *as* learning where the purpose of the assessment is sustainability. The aim of it is to treat students as critical assessors (Earl, 2003) where they are engaged in the learning, monitoring their progress, reflecting critically on their learning, and suggesting areas for improvement (Almqvist et al., 2017; Mutch, 2012). The table below shows a summary of the three types of assessments.

Purposes	Improvement →	Accountability →	Sustainability →
Type	Assessment *for* learning	Assessment *of* learning	Assessment *as* learning
Approach	Formative Diagnostic	Summative	Mixed
Focus	Individual students The teaching process	Groups and cohorts of students Schools and teachers Stakeholder interests	Engagement, progress and achievement 'Big picture' syntheses Future predictions
Themes	Societal goals Equity and justice Teacher effectiveness	Compliance Efficiency Outcomes	Good practice Empowerment Future preparedness
Data	Test scores Attitudinal ratings Observations	Aggregated achievement data Comparative studies Variance reports	Individual engagement, progress and achievement Developmental data Comparative studies Longitudinal trends

Table (2.4): Summary of the three types of learning (Mutch, 2012; p.376).

The focus in this study is on the assessment *as* learning because it represents the authentic assessment, where the purpose is for sustainability; it uses a mixed approach; and the focus is on students' engagement, progress, achievement, big picture, and future predictions (Mutch, 2012). The sustainable assessment (assessment as learning) is focusing on training students to be purposeful and effective citizens (Mutch, 2012). The aim of this assessment is not only to acquire knowledge and skills but also to develop attitude, qualities or dispositions that remain after schooling where a change in their references occurs (Mutch, 2012). As assessment *for* learning is about improving, assessment *of* learning is about accountability, then the focus of assessment *as* learning is about critical reflection, rational discourse and perspective transformation (Mutch, 2012).

Students need to know how they learn, what will be their next step in learning, and how they will know when they get there, while teachers need to use some reflective skills that enable them to assess how their instructional activities can assist their students to be self-

reflective, independent, and critical thinkers (Mutch, 2012). In this assessment teachers and students are co-constructing and designing the type of assessment in authentic tasks that take a long time as they decide the learning steps together, build in checkpoints to monitor progress and share assessment information (Mutch, 2012). The effective pedagogy and sustainable assessment occurs when teaching is framed as an ongoing inquiry (Almqvist et al., 2017). This can be done in three steps: focusing inquiry, teaching inquiry, and learning inquiry (Almqvist et al., 2017). Focusing inquiry establishes the baseline direction where teachers try to figure out what the students need to know (Almqvist et al., 2017). This represents the "Know" stage in Drake's model of integrated curriculum. Teaching inquiry is to design teaching and learning practices that asks the question, what evidence-based strategies can be used to help students learn? (Almqvist et al., 2017; Mutch, 2012). In other words, it focuses on what students will be able to do, which is the "DO" stage in Drake's model. Finally, the learning inquiry investigates the success of teaching by figuring out what the students will be (Almqvist et al., 2017) which represent the "BE" stage in Drake's model of integrated curriculum. These three types of inquiry combine all the three assessment purposes (improvement, accountability, and sustainability). As a result, it has been shown that the authentic assessment (assessment as learning) is designed to be aligned to the transdisciplinary curriculum as they have shared characteristics and lead to transformative learning theory where students are engaged in a long process of critical reflection, rational discourse and perspective transformation that calls for sustainability (Almqvist et al., 2017).

Authentic assessment is considered to be a way that educators learn about the effectiveness of teaching and learning; however, many teachers are less familiar with the use and benefits of authentic assessments (Zilvinskis, 2015). Authentic assessments are mainly designed to bridge knowledge retained throughout the course into transformative learning opportunities that extend to their lives (Wawrzynski & Baldwin, 2014). Authentic assessment is not only like any other kind of measurements but also it emphasizes the development of students' skills that will prepare them for jobs that do not yet exist (Wawrzynski & Baldwin, 2014). Mueller (2010) defined authentic assessment as performing tasks that are related to real-world where students can demonstrate meaningful application of essential knowledge and skills. The best way to introduce authentic assessments to teachers is by differentiating between assessment and evaluation, then to incorporate appropriate evidence of learning such as: portfolios, project-based learning, and grading rubrics (Moore & Trahan, 1998). Eubanks (2009) highlighted the advantages of the authentic assessments: increase of students' motivation; educators support changes in curriculum predicated on authentic assessment

results; and creates a universal understanding of learning that increases incentives of both educators and learners. In addition, communication skills are used as a direct rating to identify curricular gaps (Zilvinskis, 2015).

It was stated that the connection between high impact practices and authentic assessments occurs through: comprehensive and constructed feedback; opportunities of reflection and integrated learning; apply and solve real-world issues and problems; and public demonstrations of learning (Kuh, O'Donnell & Reed, 2013). Using authentic assessment to reinforce student learning in high impact practices is confusing to many educators who think that engaging students in high impact practices is the authentic assessment. However, engaging students in high impact practices does not mean that they meet authentic assessment criteria but it is important to transform students' learning (Zilvinskis, 2015). The use of authentic assessment appropriately within the pedagogies and practices that require integrated knowledge has a great impact on transforming students' learning (Landy, 2015). Bant, Griffin, Flateby and Kahn (2009) stated three types of authentic assessments that enhance students' learning and are used as pedagogy of high impact practices: electronic portfolios, analytic rubrics, and online assessment communities. Electronic portfolios (E-portfolio) is used to record connections between learning and real life, also can be used as kind of reflection of intrapersonal development. Rubrics are used to guide students' learning as well as measuring the extent of applying skills in terms of critical thinking, quantitative literacy, and teamwork. Finally, online assessment is used to reduce the efforts of assessment and check appropriateness for a curriculum. Authentic assessment is known as performance assessment where the criteria focus on observing complex behaviour as well as knowledge and skills (Mueller, 2010). In this assessment, students are required to generate responses that are intertwined in a complex form of knowledge and skills in unpredictable real-world contexts (Mueller, 2010). Authentic assessment allows students to be engaged in long-term learning and can occur in any stage of a teaching programme (UNSW, 2017). Authentic assessment should be established in an environment that allows students to work, learn, create, develop a scenario, and solve problems through an instrumental learning approach; open conversation, communicate and collaborate with their peers through a communicative learning approach; and think critically, reflect on their learning, assess their learning and their peers, and provide constructive feedback through an emancipatory learning approach (Boud & Falchikov, 2005; Herrington, Reeves & Oliver, 2010; Mueller, 2010).

Authentic assessment has many benefits that impact students' learning as it promotes deep learning and motivates students to be engaged in more productive learning (Lombardi,

2008). It allows students to rehearse for the complex ambiguities of working and professional life through solving ill-structured problems (UNSW, 2017). In addition, students construct unique responses rather than selecting answers; they are involved in higher-order reasoning and think independently and creatively (Mueller, 2010). Furthermore, it increases students' awareness of the criteria of evaluation and makes them more independent, assessing and reflecting on their work as well as providing opportunities for creativity where they think divergently to complete their tasks (UNSW, 2017). There are many differences between traditional assessment and authentic assessment, as mentioned in the table below.

Dimensions	Traditional Assessment	Authentic Assessment
Structure of problems	Selecting a response	Performing a task
Learning setting	Contrived	Real-life
Cognitive activity	Recall / Recognition	Construction / Application
Learner agency	Teacher-structured	Student-structured
Application of learning	Indirect Evidence	Direct Evidence

Table (2.5): The differences between the traditional assessment and authentic assessment (Mueller, 2010).

On the other hand, authentic assessments are meaningful for students but also have significant challenges where there is potential for things to go wrong unpredictably and threaten a students' opportunity to demonstrate their capabilities and achievements. In addition, it is time consuming in terms of arranging students' unique tasks in advance, discussing their tasks and grading their work. Furthermore, if the scope of authentic assessment work is not carefully articulated, there can be a problem of having unreasonable workload for students (UNSW, 2017). Some students face more challenges in authentic assessment tasks where they feel anxious about whether they can communicate and collaborate effectively (UNSW, 2017).

It is important to note that authentic assessment can be best used in professional education programmes; authentic clinical production, problem-solving, and transdisciplinary curriculum (Lombardi, 2008). It has different forms where students take part in simulation or role play of a problem-based learning task, such as; scenario; portfolios; designing a solution; writing for publication; constructing a website; community placements; and forensic problem-solving (Mueller, 2010). Problem-based learning engages students in extended periods of time where they evaluate their previous knowledge and try to find what they need to learn in order to solve ill-structured problems (ElSayary, Forawi & Mansour, 2015). In addition, it requires

them to be engaged in collaborative and communicative learning. Scenarios are another way of authentic assessment that require students to notice critical factors in a given situation, investigate implications, and prepare and present a report about it (Mueller, 2010). Portfolios require students to understand and internalize the learning outcomes of a concept and then plan their own activities that generate validated evidence of skills mastery where reflection took place (Mueller, 2010). Designing a solution requires students to conduct a research project with surveys that will support their learning while presenting the solution to a community problem (Lombardi, 2008). Writing a journal article is another effective way for students that can be extended to engage them in editorial panels to review the work produced (UNSW, 2017). Constructing a website is also a form of authentic assessment where students are responsible to investigate conflicts and different viewpoints, as well as to study contemporary issues while developing a website in order to construct a website that serve the community (UNSW, 2017). Community placement is another way that requires students to establish their own learning outcomes with alignment to the learning objectives and reflect on the context of study (Mueller, 2010). Finally, forensic problem-solving is another way that can be set across disciplines and can integrate more than the subject; it requires students to investigate, analyze, synthesize, gather and record information in a teamwork and collaborative environment (UNSW, 2017).

The authentic assessment is designed based on backward design that involves many criteria (Wiggins, 1990). It should have well-articulated learning outcomes that reflect a real-world context; then establish clear criteria and performance standards. In addition, provide opportunities for students with a rubric in order to self-assess, observe and verify their performances in collaboration with their peers. The second stage is to design real-world conditions that have a higher chance of risk for students and ensure that students have the requisite knowledge and skills in order to examine the task from different perspectives. It should be designed in a way that allows students to use integrated knowledge from different disciplines to manage complex tasks over a sustained period of time. The final stage is managing the assessment load given to students and to provide them with opportunities to collaborate, communicate, reflect, reason, and think critically and creatively (Aitken & Pungur, 2010; Wiggins, 1990).

Liao (2016) highlighted the importance of students' reflection in authentic assessments while solving real-world problems that help in developing communication, collaboration, critical thinking, creativity and innovation, and self-direction skills that have a great impact on students' learning. In relation to how learners make sense of the world, Cranton (2006) pointed out that transformative learning is "a process of examining, questioning, validating, and

revising our perspectives" (p.23). Assessments enhance the development of students' transformative learning using a self-regulated and student-focused assessment model that allows students to be engaged in critical reflection (Fook & Sidu, 2013). Critical self-reflection has a vital role in formative assessment that transforms learning as it provides learners with the opportunities that allow them to critique assumptions and worldviews, then to hold them up for examination that either accepts or rejects them (Fook & Sidu, 2013). Black and William (1998) pointed out that students who were involved in critical reflection through formative assessments were found to be the largest group for instructional innovation. The formative assessments process can be carried out by teachers in different forms as it is considered to be an important element to transform students' learning (Fook & Sidu, 2013). The design and implementation of authentic assessments inspires teachers to shift the focus from teaching to learning (Black & William, 1998). This way of learning encourages students to construct new knowledge and build on knowledge gained previously (Cross, 1998). In addition, students benefit from working with their peers and might learn better (Annis, 1983). Assessing authentic performance is an integral part of the instructional cycle because the formative feedback provided by their teachers and peers helps learners assess their strengths and weaknesses as well as identifying new areas needed for growth (Fook & Sidu, 2013). It is believed that formative assessment practices help in creating options for divergent learners and higher-order thinking (Fook & Sidu, 2013).

A heuristic rubric cube has been introduced by Yen & Hynes (2012) that is designed for authentic assessment validation. They cohesively assemble three dimensions (cognitive, behavioural/psychomotor, and affective taxonomies; stakes of an assessment; and reliability and validity).

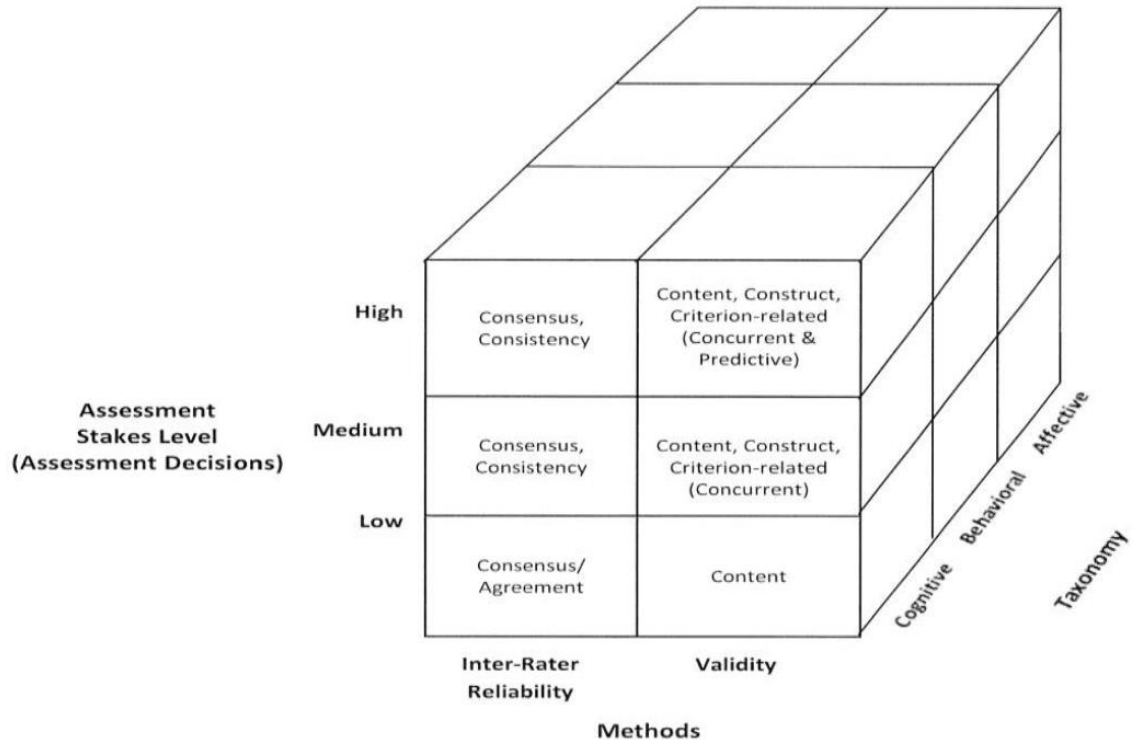

Figure (2.8): Heuristic Rubric Cube presented by Yen & Hynes (2012).

The heuristic rubric cube has three dimensions: height is the assessment stakes level (assessment decision); width is representing two methodological approaches of validity and reliability; and depth is representing the three learning taxonomies (cognitive, behavioural/psychomotor, and affective) (Yen & Hynes, 2012). Regarding the assessment stakes level, it was stated that the acceptable method used for the low level of assessment context is different than the method required for the high level of assessment context (Yen & Hynes, 2012). This is because the low level of assessment requires *demonstration* of validity and reliability while the high level of assessment requires *evidence* of validity and reliability to be shown (Wilkerson & Lang, 2003). From the stakeholders' perspective, the low level of assessment is used to assess the students' progress; the moderate-level of assessment is used to assess the moderating outcomes (work-study, experience, flow of projects, etc.); and the high-level assessment is used to assess the mission-critical learning outcome (Yen & Hynes, 2012). Regarding validity, the content validity should be demonstrated in the low level of assessment; content, construct, and criterion-related validity need to be demonstrated in the moderate-level of assessment; all the validity shown in the previous two levels should be demonstrated in the high level of assessment in addition to the predictive validity (Yen & Hynes, 2012). Regarding inter-rater reliability estimation, a percentage of consensus needs to be demonstrated, however for the moderate-level and high-level, the consensus and consistency need to be demonstrated

(Thorndike & Hagen, 1997). The reason that inter-rater reliability used in this cube is that it is a critical estimate that comprises the basis of a rubric score (Stemler, 2004). The last dimension of the heuristic rubric cube is the taxonomy that represents the depth of knowledge and skills used across three domains (cognitive, behavioural/psychomotor, and affective) to low, moderate and high-level depend on the criteria of each skill, whether all of it is to be covered or only parts of it (Yen & Hynes, 2012).The cognitive domain occurs in the emancipatory learning, behavioural/psychomotor in the instrumental learning, and affective domain in the communicative learning (Singleton, 2015).

2.5 Alignment of Transdisciplinary Curriculum and Authentic Assessment

Constructivism is the backbone of designing integrated units that are aligned to the outcomes of industry expectations (ElSayary, Forawi & Mansour, 2015) and to the assessments that are rich in contexts of performance in the real world (Wiggins, 1990). Ashford-Rowe, Herrington and Brown (2014) mentioned key important elements to be considered in designing authentic tasks, while Guzey, Moore and Harwell (2016) stated similar key elements in designing the integrated curriculum. The commonality of the key elements between authentic assessment and an integrated curriculum were identified as the following: challenge; performance or outcome product; transfer of knowledge; metacognition; accuracy; fidelity; discussion; and collaboration. The degree of challenge reflects the authenticity of real-world problems and tasks where students are required to demonstrate their ability to analyze the task and synthesize from the range of knowledge and skills they have acquired (Ashford-Rowe, Herrington & Brown, 2014), in addition to motivation that allows them to be engaged in the context (Guzey, Moore & Harwell, 2016). Students should be able to demonstrate skills and knowledge by being engaged in complex and authentic performance to create a significant product (outcome) using higher-order thinking, problem-solving, and creativity (Archbald & Newmann, 1988; Ashford-Rowe et al., 2014; Guzey et al., 2016). There is a strong relationship between the requirement to demonstrate specific skills and knowledge and the importance of producing successful performance and product (Ashford-Rowe et al., 2014) where they can transfer it to new concepts (Guzey et al., 2016). In authentic assessment work or performance, knowledge should be designed from a range of domains to be integrated in order to produce an innovative product (Ashford-Rowe, et al., 2014). This is the essence of integrated knowledge and authentic assessment that aims to integrate skills and knowledge from different disciplines that leads to students' transformational learning (Ashford-Rowe et al., 2014; Guzey et al., 2016).

Metacognition determines the value and significance of critical reflection and self-evaluation for successful workplace performance (Ashford-Rowe et al., 2014) where learning from failure and reflection are a critical part (Guzey et al., 2016). The significance of the metacognition to learning process is enhancing deep learning by enabling links to be made within and between content areas and disciplines (Ashford-Rowe et al., 2014). The accuracy of the authentic assessment in addressing the needs of the real world reflects on the assessment value in two dimensions: first, the aims to measure the extent of the learners' intellectual input required in the development of the product; second, the measure of a real-world test of ability rather than just matching items to curriculum content (Ashford-Rowe et al., 2014; Herrington & Herrington, 2006). The definition of the tools may include broader cultural elements such as appropriate language, graphics, and topics to let the students feel more familiar with the assessment task (Kendle & Northcote, 2001). Feedback is vital in the process of the assessment because it benefits the learners' interpersonal skills, logic, and rhetoric (Newmann & Wehlage, 1993). The collaboration between students where feedback and discussion are integral elements of authentic learning activities allows for divergence learning; giving students' responsibilities; and helping them to see the value of what they are learning (Ashford-Rowe et al., 2014; Lebow and Wager, 1994). Experts emphasized that the integrated curriculum should be relevant, standards-based, and meaningful in order to ensure the aims and relevancy of the disciplines (Drake & Reid, 2010; Drake & Burns, 2004). In order to transform students' learning, instructions are required to be not only aligned with the integrated curriculum and authentic assessment but also to connect learning within students' minds (Drake & Reid, 2010).

Black, Wilson and Yao (2011) highlighted that the assessment must be understood as essential core activities in the work of teachers, due to the implications of students' learning from the feedback and reflection given to them, in addition to modifying teaching and learning activities in order to meet students' needs. Black, Wilson and Yao (2011) mentioned three main implications of feedback in communicative learning: oral dialogue, peer group dialogue, and written work. Oral dialogue is aiming to promote active participation of classroom members to develop students' understanding of concepts and then ask students to clarify, compare, challenge and defend their responses or ideas. In this activity, teachers play a variety of roles, to be challenger, summarizer, provocateur, and rules setter for argument and discussion. First, teachers need to start the discussion with a variety of questions, then listen to the students' responses and start guiding students to summarize or highlight contradictions. Furthermore, developing students' learning skills is an essential feature of learning dialogue (Applebee et al., 2003; Black, Wilson & Yao, 2011; Smith et al., 2004).

The peer group dialogue is another implication mentioned, where the work alternates between the whole class activity and students' discussion in small groups (Black, Wilson & Yao, 2011). There is a distinctive value of learning when students enter into peer dialogue as they use language and thinking within their zone of proximal development which helps them to understand better (Black, Wilson & Yao, 2011). In this dialogue, each group of students are responsible to appraise and compare their work with each other; sort the work and order it in levels of sophistication; and formulate and agree on criteria of quality. Teachers here are guiding students to develop a clear aim and criteria of the work quality and students work toward this aim. This metacognition awareness of students' learning helps in developing students' autonomy of their learning to be self-directed learners.

The written work is the last implication of Black, Wilson and Yao (2011) where the written comments provided to students on their work help them to tackle the weaknesses they have and improve their learning. Teachers here set the route for students' learning by formulating tasks where responses provide evidence of students' progress. In addition, they give helpful comments and feedback that are tailored to students' needs and give clear guidance about how to improve. Some students need help by reminding them of their achievements from the comments provided. This in turn develops students' motivation and changes their attitudes toward learning. Some research studies mention the balance between task involvement and ego involvement of learners (Butler, 1988; Butler & Neuman, 1995; Dweck, 2000). Students who have continual labelling of their work with marks, grades and the publication of test scores shift their attitudes toward ego involvement which leads to poor test results (Butler, 1988; Butler & Neuman, 1995; Dweck, 2000). Students need to shift from the culture of competition to the culture of collaboration where they can monitor their progress against criteria of progression.

Pedagogy is set as the connection between curriculum and assessment where attention should be taken to focus on the sequence of designing and implementing any learning exercise (Black, Wilson & Yao, 2011; Hallam & Ireson, 1999; Tyler, 1949; Wiske, 1999). Black et al. (2011) proposed a model of pedagogy that focuses on five main steps: strategic aim; planning the teaching; implementing the teaching plan; review through formal testing for formative purposes; and review through formal testing for summative purposes. The strategic aim is set as the first step where the priority is given to developing understanding of concepts and skills of the subject. Then, focus on developing particular reasoning skills. In the second step, the important criterion in planning the teaching is the potential of any activity to elicit responses (oral or written) that help to have a clear image about learners' previous understanding and

prepare them for the next challenge. This design of activity is full of oral dialogue and various forms of written work that help in developing interaction and communication between learners. The third step is the implementation of the teaching plan that ensures the existence of the oral dialogue, peer group dialogue and written work. It is the most important step that is considered to be the first move toward transforming students' learning and has not been clarified by many researchers before (Black et al., 2011). There are two problems that exist in this step: the requirement of teaching is the re-appraisal of the way teachers perceive their roles; and that the reaction of learners is often unpredictable. The fourth step is reviewing the teaching and learning process through formative testing that has two purposes. First, the reflective purpose that aims to overview the learners' progress in order to develop their learning as well as checking misconceptions or gaps. The second purpose is the prospective purpose that aims to build on students' learning and start challenging them by transferring what they have learned into new concepts. Finally, there is the summing up of learning through formal testing for summative purposes where the outcomes are interpreted and used for several purposes, such as: celebration, motivation or guidance of students in their overall progress; shifting them to the next phase of learning or employment; guide for teachers to the effectiveness of work; for the school, can be used as a tool to inform the accountability of the teacher or school.

Gross and Gross (2016) pointed out that students should take into consideration their failure along with feedback from presentations to further refine their products. As a result of experimentation and failure, students are engaged in deep inquiry producing less products and consuming more materials (Gross & Gross, 2016). Jacob (1989) mentioned that subjects in the real world do not exist in isolation, in fact, the use of real-world problems and situations assesses students' ability in gathering information and data from multiple sources.

2.6 Emancipatory, Communicative and Instrumental Learning

Mezirow's (1997) theory is driven from Haberman's (1984) ideas about the basic three kinds of learning: instrumental, communicative, and emancipatory learning. Cranton (1996) suggested three types of reflection that transform learning and are embedded within the three types of learning: content reflection; process reflection; and premise reflection, and referred to them as "What", "How", and "Why". Content reflection is recalling of the information of what students already know (Cranton, 1996). It is known as the examination of the description of the problem. It should be the first step of the learning process in order to know the extent of accepting the situation (Owen, 2016). Process reflection comes as the next step after a new

understanding has been developed (Cranton, 1994). Owen (2016) mentioned that the process reflection is checking perceptions through problem-solving strategies. This leads to the premise reflection, that is, to questioning the problem based on the developed perception and awareness of the situation or problem (Cranton, 1994).

Transformative learning theory has been applied to adults as it was assumed that children are not able to experience and critically reflect on their learning that leads to transformation (Merriam, 2004; Taylor, 2007). However, research has proved that transformative learning theory is more effective when it is started with children at a young age as they are capable to be self-regulated regarding their learning, having curiosity that motivates them to be engaged, and reflect critically on their learning (National Research Council, 2000; Singleton, 2015). Dewey (1934) emphasized the role of reflection that enriches the possibility of experience that changes learners' relationship with the world, a new way of viewing the world, and a new way to exist in the world that is transformative. The critical reflection took place in the process of authentic assessment where students were engaged actively on a task over a long period (Sipos et al., 2008). In addition, Pugh and Girod (2007) emphasized that sciences have the same potential of art to enrich everyday experience that leads to transformative learning. Furthermore, adding art to STEM subjects allows students to be involved in different types of learning that leads to transforming their frame of reference (perception) especially when they critically reflect and self-assess their work in authentic assessment tasks (Gettings, 2017; Liao, 2016). Sipos et al. (2008) highlighted the importance of the link between authentic assessment and integrated disciplines that affect students' intellect, emotion and body, which leads to transformative learning. Orr (1992) presented a model of transformative learning that was expanded by Sipos et al. (2008) which is called Head, Heart, and Hand. Sipos et al. (2008) defined the intellect as the cognitive domain that occurs within emancipatory learning (Head); emotion is implied in values and attitudes that are acquired through communicative learning (Heart); and body as the psychomotor domain that requires the development of skills and physical work (Hand). The Head refers to the role of reflection and critical thinking; these are considered the most important factor of metacognition and the most neglected element in implementation (Singleton, 2015). Many researchers point out that aligning authentic assessment with a transdisciplinary STEAM curriculum allows students to be involved in the three types of learning mentioned above that lead to transformative learning (Gettings, 2017; Liao, 2016; Owen, 2016; Guzey et al., 2016).

The Head in this model refers to the use of critical reflection where emancipatory learning takes place (Singleton, 2015). The function of reflection is to connect between

learners' experience and their previous experience, knowledge and ideas (Dewey, 1910; Kolb, 1984; Robert, 2002). Research on how the brain works found that the brain's natural way of extracting meaning and integrating new knowledge with prior knowledge is by comparing new experience with prior experience (Jensen, 2008; Ross & Olsen, 1993). Reflection is an essential element of transformational experiences (Mezirow, 1978; Taylor, 2007) and of metacognition and constructivist learning practices but it is the most neglected due to the time needed (Baviskar, Hartle & Whitney, 2009). In addition, most teachers are not trained to guide students for reflective practices, with the result that the curriculum might be covered in breadth but not in depth (Singleton, 2015). Emancipatory learning has been defined as intellectual and affective activities that learners engage in to explore their experiences and reflect on them in order to construct new understanding (Boud et al., 1985). There are different levels of reflection on one's experience, from surface descriptions to deeper analysis and synthesis, which are the transformative learning outcomes (Ballantyne et al., 2010). The deeper level is more difficult to reach and less frequently demonstrated (Mann et al., 2007). Self-reflection tasks enrich learners with self-awareness and make the process more explicit, in addition to the development of metacognitive and critical thinking skills (Desautel, 2009).

The Heart in this model refers to the use of relational knowing that occurs in communicative learning (Singleton, 2015). Quality of life is dependent upon relationships with environments, communities, and personal relations (Singleton, 2015). The relation and interconnection between learners' senses and the world is the gateway to perception (Blenkinsop, 2005). Relational knowing is defined as the awareness of one's relationship with the community and the world (Riley-Taylor, 2004). There are four categories of relational knowing: thinking, feeling, intuition, and sensation (Cajete, 1999). The rational forms of intelligence, logic and linguistic, are valued over other ways of knowing such as emotional intelligence (Singleton, 2015). As learners have fundamental needs of belonging, relationship is considered to have a powerful effect on learners' emotions, thoughts, and behaviours (Baumeister & Leary, 1995). The significant emotional event is the impetus of change to transform where the community relationship transforms pointless living into meaningful experiences (Shapiro, 2006; Singleton, 2015). Communicative learning is aiming to advance learners' understanding of human communication (Mezirow, 2003). This form of learning involves the interpreting of values, feelings, intentions, moral decisions and normative concepts (Diduck & Mitchell, 2003). In other words, it is to negotiate purpose, values and feelings rather than acting on those of others (Mezirow & Associates, 2000). The essence of this learning "involves assessing claims to rightness, sincerity, authenticity, and

appropriateness" (Mezirow, 2003, p.59). In order to do this, students should attempt to reach a common understanding with others; however, this is subject to change if new information calls it into question (Mezirow, 1994). The learning outcomes stated by Quinn & Sinclair (2016) are categorized in three main points: insight into one's own values and interests; insight into values and interests of others; insight into shared values and goals.

The Hand in this model refers to the deep engagement through the instrumental learning (Singleton, 2015). The active use of concepts leads to incorporating educational experiences into everyday life (Singleton, 2015). Engaged learners are more attracted to their tasks despite challenges or obstacles they might face (Schlechty, 1994). There are four goals that motivate students to be engaged in an instrumental learning environment: success and mastery of skills, curiosity and understanding, originality and self-expression, relationship and involvement with others (Strong, Silver & Robinson, 1995). The main purpose of instrumental learning is to develop and enhance the knowledge of both concrete and rational spheres of the individual's understanding (Diduck & Mitchell, 2003; Mezirow, 1994). It is the process whereby learners enhance their proficiencies, knowledge, and understanding as well as anticipating the future outcomes (Quinn & Sinclair, 2016). The presence of a transdisciplinary STEAM curriculum allows learners to be engaged in the instrumental learning process to analyze, synthesize, create, reflect, think critically, etc. (Costantino, 2018; Gross & Gross, 2016; Hunter-Doniger & Sydow, 2016; Perignat & Katz-Buonincontro, 2018). The essence of this learning process is assessing truth claims which requires learners to discover whether "something is as it is purported to be" (Mezirow, 2003, p.59). The premise in assessment is viewed to be a task-oriented process that involves empirical testing (Quinn & Sinclair, 2016). Several outcomes of instrumental learning have been stated by Quinn & Sinclair (2016) that lies in three main categories: physical and mental skills; knowledge; and cognitive understanding. There is a strong and unique engagement of students when they are provided with challenging tasks in authentic environments (Fredrick et al., 2004). Furthermore, students are more motivated to be engaged in their learning when they can transfer what they have learned to do something that has a positive impact on others or their community (Singleton, 2015).

The Head, Heart and Hand model of transformative learning is considered to organize principles that aim to integrate and transform pedagogical perspectives for sustainability education (Sipos et al., 2008). The essential elements of transformation are the use of: critical reflection in an emancipatory learning environment; relational knowing in a communicative learning environment; and deep engagement in an instrumental learning environment (Singleton, 2015). These all should be guided through in order to engage students in authentic

contexts using integrated knowledge that will have a great impact on making learning more meaningful (Singleton, 2015). Adding to that, the more there is complexity of integration in a complex authentic task, the more probability to transform learning occurs (Getting, 2017; Gross & Gross, 2016; Liao, 2016; Miller, 2017).

2.7 Previous Studies

Drake & Reid's (2017) stated in their study about assessing the 21st century integrated curriculum, that assessment was a challenge for teachers where the main focus was on the nature of integrated knowledge and less prominence was given to ways of assessing students' integrated learning. Deep learning that is focused on student-centred, concept-based and skill-enhancing student-teacher learning partnership, effective use of technology, and diverse instructional activities and assessments are needed to meet the needs and characteristics of students (Australian Curriculum, Assessment and Reporting Authority, 2013; Brooks & Holmes, 2014; Fullan & Langworthy, 2014; Ontario Ministry of Education, 2015; Singapore Ministry of Education, 2010). Transdisciplinary learning is aligned with the 21st century pedagogy that is being implemented around the world (Drake & Savage, 2016; Savage & Drake, 2016). There is no doubt that the student-driven approach in a meaningful learning environment is influenced by the use of the transdisciplinary curriculum where students are engaged in authentic assessment tasks (Boix-Mansilla & Gardner, 2005; Breunig, 2017; Buck Institute for Education, 2016; Drake, Reid & Kolohon, 2014; Ghosh, 2017; Greenhill et al., 2018; Merilainen & Piispanen, 2013; Naidoo & Kirch, 2016; Turner, 2015; Vasquez, Sneider & Comer, 2013). Furthermore, transdisciplinary learning fosters the shift from the acquisition of facts to learning around the big idea and enduring understanding (Erickson, 2008; Ontario Ministry of Education, 2015). The big ideas and enduring understanding of a real-life problem are providing a rich and relevant context for explicit teaching and learning where the transdisciplinary content and skills are experienced (Rotherham & Willingham, 2009). Researchers state that the transdisciplinary curriculum allows students to be more engaged and motivated in learning where they perform better than learning in separate subject classes (Drake, Savage, Reid, Bernard & Beres, 2016; Reeves, 2009). Teachers as well as students are benefiting from being engaged in an integrated curriculum which encourages professional growth among them (Drake & Reid, 2017). Teachers in a previous study stated that the integrated units fostered higher-order questioning and greater differentiation of instruction and assessment that led to a higher expectation of students' performances (Drake & Reid, 2017).

Four interconnected themes have emerged in the use of authentic assessment tasks within the integrated curriculum: increased depth and diversity of assessment tasks; increased efficiency; deeper assessment literacy among students and teachers; and the challenge of reporting (Drake & Reid, 2017). In order to increase the depth and diversity in classroom assessment, establishing validity is an important factor through the use of the backward design curriculum planning model (Drake, 2007; Wiggins & McTighe, 2005). This lies in starting with the big idea and enduring understanding (Know), and the transdisciplinary skills (DO) based on the required standards (Drake & Reid, 2017). Then, teachers start to create a rich summative assessment aligned to the desired outcomes. Finally, teachers plan the daily instructional activities that include embedded authentic assessment (assessment as learning) (Drake & Reid, 2017). In addition, increasing efficiency in classroom assessment is done through the rich authentic assessment tasks where teachers are able to assess expectations in more than one subject at once (Drake & Reid, 2017). It has been stated that a lower amount of content taught in depth with rich authentic tasks might be more beneficial for students, where they master the skills and acquire knowledge that enable them to use what they have learned in new situations (Drake, Savage, Reid, Bernard & Beres, 2016). Furthermore, aligning assessment with the curriculum standards using backward design allows for acquiring deep assessment literacy (Drake & Reid, 2017). The use of authentic assessment along with the transdisciplinary curriculum allows for more choices and differentiated tasks where students take part in the planning, along with their teachers (Drake & Reid, 2017).

Another challenge that teachers experience in assessing an integrated curriculum is on the report cards, where they feel lost when trying to report students' marks (Drake & Reid, 2017). The use of authentic assessment with a transdisciplinary curriculum allows for using many and different concepts integrated and therefore teachers are unable to report students' marks in separate subjects, and some teachers were even not sure if the required standards had been covered because the focus is on real-life application (Drake & Reid, 2017). One of the challenges faced in the design of STEAM contents is that they focus on science or mathematics subjects and seldom on engineering and technology (Herro & Quigley, 2017). A study by Doniger & Sydow (2016) mentioned that exposing students to real-life problems that require integrated STEAM subjects has a positive impact on increasing students' results in standardized assessments.

In a study by Gross & Gross (2016), the theme of using authentic assessments with transdisciplinary STEAM enhanced students' transformational learning as students were able to create projects that went far beyond the expectations due to the socio-cultural environment

where communicative learning took place. Another study (Liao, 2016) emphasized the importance of designing a transdisciplinary STEAM in order to address social and global issues that lead to students' transformational learning. Sousa and Pilecki (2013) emphasized that integrating art to STEM has a great impact on transforming students' learning as it shifts the curriculum from interdisciplinary to transdisciplinary, which is considered to be the strongest integration between subjects. This is due to the integration between the methods of art and STEM. Furthermore, Gettings (2017) highlighted that the transdisciplinary STEAM requires students to go through different types of learning that force them to use a wide variety of habits of mind that lead to transformative learning. Miller (2017) mentioned the challenges educators face in transforming students' STEAM learning, such as standardized assessments, lack of teachers' preparation, and limited resources. Accordingly, the alignment of STEAM to authentic assessment gives students opportunities to be exposed to the emancipatory, communicative and instrumental learning through solving complex problems in project-based approach and self-assess their own learning and their peers', where students reflect and provide feedback (Miller, 2017). Students who build relationships with peers, community, and world, critically reflect on their learning and are active learners in their classrooms are more likely to transform their perspectives, change behaviours and be engaged in sustainable community practices (Singleton, 2015). In transformative learning, assessment occurs as part of learning over an extended period of time where students are engaged in authentic and complex task in order to examine their beliefs and assumptions (Goulet, 2010). The skills acquired are not easy to measure and require multiple tools in order to measure them, such as standardized assessments, students' reflection, observations, and global rating scales (Lai & Viering, 2012). A study of Lieberman and Mace (2008) stated that the successful collaboration of teachers and school leaders leads to successful implementation of the curriculum that develops students' skills, achievements, and innovation. Beghetto (2015) claimed that the teachers' beliefs about the learning practices don't transform students' learning as there is tension to prepare students to perform well in the fact-based assessments. However, Corply (2015) stated that STEAM education fosters students' skills due to the focus on the cognitive, metacognitive and collaboration processes.

2.8 Summary of the Literature

The constructivism is used as the backbone of the study. There are two main approaches of constructivism: cognitive and social constructivism. Cognitive constructivism is based on Piaget's theory that concentrates on the importance of the mind in learning (Ornstien &

Hunkins, 2014). Piaget mentioned three important points in the process of cognitive development: accommodation, assimilation, and equilibration that have been emphasized and developed by Taba (Ornstien & Hunkins, 2014).

Accommodation is to move from concrete experiences to concepts, principles, and enduring understanding that requires integrated knowledge (Ornstien & Hunkins, 2014). Integration between disciplines allows for more concepts to be taught in less time and at higher level (Drake & Reid, 2010; Jacobs, 1989). Drake (2007) and Beane (1991) built their models based on the accommodation of the cognitive development where their focus was on the types of integrated curriculum that has been known as multidisciplinary, interdisciplinary and transdisciplinary. The transdisciplinary curriculum is considered to be the most complex integration where adding the art to STEM allows students to be engaged in cognitive, physical and emotional activities that are considered to be the basics of human experiences and necessary for survival (Sousa & Pilecki, 2013). In addition, it allows students to use both sides of the brain where STEM is representing the left side (objective, logical, analytical, and reproducible characters) and the art represents the right side (subjective, intuitive, sensual, unique, and frivolous characters) (Sousa & Pilecki, 2013). It was stated that adding art to STEM allow students to shift between convergent and divergent thinking that lead to higher level of creativity (Corply, 2015; Costantino, 2018; Gettings, 2017; Gross & Gross, 2016; Katz-Buonincontro, 2018; Perignat et al., 2018).

The second important stage in Piaget cognitive development process is assimilation which is organizing curriculum and teaching new experience (Ornstien & Hunkins, 2014). The constructive alignment theory of Biggs (1996) is based on this stage where it relies in aligning between curriculum, assessment and instructions. This is the main purpose of the study where there should be alignment between transdisciplinary STEAM curriculum and authentic assessment. The authentic assessment tasks are described as social cognitive pedagogies that engage learners in procedural learning processes (Bass, 2014). Social constructivism is when students interact socially along with a personal critical thinking process (Vygotsky, 1962). One of the main elements of Vygotsky's theory is the Zone of Proximal Development (ZPD) where learners learn easily when others are involved and interact with them (Vygotsky, 1962). Cognitive constructivism heavily emphasizes the reasoning ability of learners and how they interpret knowledge based on their personal experiences, while social constructivism considers the variables of social interaction, culture and language that affect the ways learners learn (Powell and Kalina, 2009) which are all considered in the three types of learning. Earl (2003) shifted the balance from focusing on assessment of learning to focus on assessment as learning

which is named later as authentic assessment. This is because the purpose of authentic assessment is self-monitoring and self-correction or adjustment where the key assessor is the student using their personal goals and external standards as their reference points (Earl, 2003). Lichfield & Dempsey (2015) mentioned the importance of moving the model from traditional assessment into the authentic assessment as it involves several checking points for students to allow them to receive feedback and reflect on their learning. The learning and training center of Marquise University (2008) mentioned the difference between traditional and authentic assessment where traditional assessment relies on selecting a response, recalling information, teacher-structured, and has indirect evidence. However, the authentic assessment relies on performing a task, uses real-life application, student-structured, and requires direct evidences (Marquise University, 2008).

The last stage of piaget cognitive development process is the equilibration which is classifying and understanding new relationships where it is considered to be shift toward transformative learning (Ornstien & Hunkins, 2014). Mezirow criticized the constructivism theory as it needs various degree of structured teaching and learning (Kaufman, 2003). Mezirow (1997) mentioned that transformation takes place when students points of view and habits of mind change. The points of view are change in students' beliefs, judgement and attitudes. They are easy to change as they are based on empirical evidences which is named later by "little t" (Pugh, 2015). In order to change students' points of view, it is required that students should be engaged in critical reflection (emancipatory learning), rational discourse (communicative learning), and centrality of experience (instrumental learning). The critical reflection is a purposeful critical analysis of knowledge. The rational discourse is a process of dialogue to validate individual's experiences. Finally, the centrality of experiences is to bring new ways of defining the world (Pugh, 2015). It is also called as transformative experience where the continues use of it lead to the "big T" which is the change in students' habits of mind. They are not easy to change as it transforms the way students think, act and feel that requires reflective thinking (Pugh, 2015). Cranton (1996) pointed out that students' habits of mind changed when they reflect on the content, process and premise within each type of learning by asking themselves: what, how and why. Reflection on the content is examination of the problem description where students recall information, it causes change in their assumptions (Cranton, 1994). Reflection on process is checking perceptions through problem solving strategies that cause change in their perspectives. Finally, reflection on premise is to question the problem based on the developed perceptions that cause change in students' behaviors (Cranton, 1994).

The next chapter presents the multiphase mixed method used in this study and the tools used in order to find the results and interpret findings that address the research questions. The chapter involves the research design, methodology, participants, tools, data collection, and process of data analysis in details.

Chapter 3: Methodology

This research is a case study carried out over a period of six months in a public school in United Arab Emirates (UAE) that implements the transdisciplinary STEAM curriculum. The study aims to investigate the impact of designing a transdisciplinary STEAM curriculum and authentic assessment on transforming students' learning. Accordingly, this study is designed to seek for breadth in order to cover many aspects that lead to the same phenomena. Thus, a multiphase mixed-method approach is followed in this study with two different phases using multiple instruments. The first phase of the study included document analysis and a questionnaire for the curriculum developers and teachers, while the second phase included a quasi-experiment and focus group discussion. The first phase starts concurrently with the second phase, however, within each phase the data is collected sequentially. The results of the first and second phases are interpreted separately then they are compared and integrated in the discussion to fulfill the main purpose of the study.

The chapter starts by presenting the research design, site, instrumentation, population, sample and participants, validity and reliability, and ethical considerations.

3.1 Research Approach

A mixed-method research design is used in this study to include both qualitative and quantitative methods that have different forms. This refers to pragmatic philosophy that lies in collecting a thoughtful combination of qualitative and quantitative data that serve and address the main purpose of the study (Johnson & Christensen, 2014). It goes beyond qualitative and quantitative approaches to adopt "what practically works" (Creswell, 2014). The mixed-method research is a third methodological paradigm that over the past twenty years has provided legitimation compared to the traditions of quantitative and qualitative movements (Tashakkori & Teddlie, 2010; Teddlie & Tashakkori, 2009). The paradigm shift to the mixed-method is due to the attack undertaken on the positivist paradigm of quantitative research from the social scientists who were supporting the qualitative research and proposing constructivism (Reichhardt & Rallis, 1994). Guba and Lincoln (1994) stated that finding a rationale for a mixed-method approach set as a problem due to the incompatibility of combining qualitative and quantitative data. There are several characteristics of pragmatism that are discussed below. The pragmatism implies in finding a middle ground between philosophical dogmatisms and skepticism and to find a workable solution (Johnson & Christensen, 2014). It rejects the

traditional dualisms and prefers more commonsense versions of philosophical dualisms based on how well they work to solve problems. In addition, it recognizes the importance and existence of the natural world as well as the social and psychological world that includes language, culture, thoughts, and institutions (Johnson & Christensen, 2014). In pragmatism, knowledge is constructed and based on the reality of the world we experience (Johnson & Christensen, 2014). Fallibilism is another characteristic that is endorsed by pragmatism which means perfectionism in the current beliefs and research conclusions. Dialectic pragmatism (also called pragmatism) offers the philosophy that best supports mixed research. The "dialectic paradigm" is research that uses multiple paradigms and an integrated perspective that allows for the synthesizing back and forth of multiple perspectives needed in the research (Johnson & Christensen, 2014). The dialectical pragmatism has been extended and transformed to a fully developed philosophy and metaparadigm that is called "dialectical pluralism" (Johnson & Stefurak, 2013). It assumes that reality has different disciplines and levels that are multifaceted and plural, subjective, intersubjective and objective (Johnson, Onwuegbuzie, Tucker, and Icenogle, 2014). Also, it relies mainly on dialectical and dialogical approaches to discussion, learning from differences, and produces team based research products.

Dewey extended the works of Peirce (1905) and James (1907) in applying pragmatic principles in developing his philosophy (1944). Dewey believed that considering consequences while discovering the meaning of the idea is most important (1920). In other words, the empirical and practical consequences should be considered before judging ideas by examining them in order to understand the philosophical positions and help in deciding which action to take to better understand real-world phenomena (Johnson & Onwuegbuzie, 2004). Dewey stated that the pragmatic researcher tries to provide strong evidence that meets the epistemological standard that is called "warranted assertability" (Johnson & Christensen, 2014).

The pragmatist is concerned more about what works rather than anticipating final proof, through shedding light on how research approaches can be mixed fruitfully (Hoshmand, 2003). The advantage of using a mixed research design is to benefit from the strengths of qualitative and quantitative methods while minimizing the weaknesses that might occur in a single method (Brewer & Hunter, 1989; Johnson & Turner, 2003). One of the fundamental principles of mixed method is combining quantitative and qualitative data in a way that has multiple directions (convergent and divergent); complementary strengths that are broadly viewed; and non-overlapping weaknesses (Johnson & Christensen, 2014). The combination of using quantitative and qualitative data begins with the assumption that researchers gather evidence

based on the nature of the question and theoretical orientation (Pasick et al., 2009). The quantitative approach is mainly a deductive method that is ideal for measuring known phenomena including assumptions and inferences of causality, while qualitative which is an inductive method is used to identify a previously unknown process or explain why and how phenomena occur (Pasick et al., 2009). The integration of quantitative and qualitative data has different forms that are known as: merging data, connecting data, and embedding data (Creswell & Plano Clark, 2011). The two types of merging data and connecting data are followed in this study. The merging data is used in the two phases of the study within a sequential mixed method approach. Merging data means that one form of data is used to support or refute the result of the other form (Sandelowski, Voils & Knafl, 2009). Connecting data is used with the results of the two phases of the study where the data of each phase is analyzed and interpreted separately and then the data of the two phases is connected to fulfill the main purpose of the study. Creswell (2003) mentioned several criteria to be used for the mixed research: priority, implementation, integration, and theoretical perspective. According to Johnson and Christensen (2014), there are eight iterative steps that are important to conduct a mixed research study and which were considered in designing this study: the appropriateness of the mixed-design; rationale; sampling design; constructing the research design; analyzing data; validating data; interpreting findings; and writing the final report. The study aims to have an equal weight of qualitative and quantitative data. There are some limitations of conducting mixed research where it requires more time and resources; expertise in designing and implementing both quantitative and qualitative phases; which sometimes yield contradictory findings (Johnson & Christensen, 2014).

In order to investigate the impact of transformational learning, different projects should be conducted that lead to the same phenomena. The multiphase design emerges from multiple projects conducted and linked together by a common purpose (Creswell & Clark, 2011). Accordingly, the implementation of the study is multiphase mixed-method that combines concurrent and sequential in two different phases. Creswell (2014) stated that the multiphase mixed-method is an advanced design that uses several mixed projects which lead to the same phenomena. The multiphase mixed method uses a set of research questions using different projects that all fulfill the main purpose of the study (Creswell & Clark, 2011). A multiphase mixed-method benefits from a strong theoretical perspective (pragmatism) that provides a guiding framework for thinking about different aspects of the study across the multiple phases (Creswell & Clark, 2011). According to Creswell and Clark (2011), this design has many strengths. First, it has flexibility to utilize the elements that are required to address a set of

interconnected research questions. Second, this research can be treated as different studies that are sharing the same objectives. Finally, this research can provide an overall framework for conducting iterative studies over multiple years. Also, there are some challenges of the multiphase mixed method (Creswell & Clark, 2011). First, the researcher needs sufficient resources, time, and effort to successfully implement multiple phases. Second, the researcher needs to know how effectively to connect individual studies in addition to connecting quantitative and qualitative data within each phase. Third, results from each phase can be disseminated, interpreted and published individually in order to obtain feedback on the design and contents. Finally, the researcher compares and integrates findings to fulfill the main purpose of the study. There are various purposes of multiphase design that can be used as: large-scale program development and evaluation projects; multilevel statewide studies; and single mixed-method studies that combine both concurrent and sequential phases (Creswell & Clark, 2011). The last variant of a multiphase mixed method is used in this study as it lies in using both concurrent and sequential approaches. The mixed projects can be conducted sequentially and/or concurrently. The two phases of this study were conducted concurrently; however, within each phase the data was collected sequentially.

The rationale of the main purpose of this study is attempting to expand the breadth and range of investigations by using different methods for different inquiry components that is called "expansion" (Johnson & Christensen, 2014). Creswell (2003) mentioned that the theoretical lens of the research design could be explicit or implicit according to the research design. In this study, the theoretical lens is implicit as the study is using sequential mixed method within each phase.

As presented in the first chapter, this study was undertaken to address the following questions:

1. How is authentic assessment planned in a transdisciplinary STEAM curriculum?
2. What are the curriculum developers' and teachers' perceptions and practices in designing and planning a transdisciplinary STEAM curriculum?
3. What changes, if any, do emancipatory, communicative, and instrumental learning have on transforming students' learning?
4. How does the students' frame of reference vary after being exposed to the transdisciplinary course and authentic assessment?

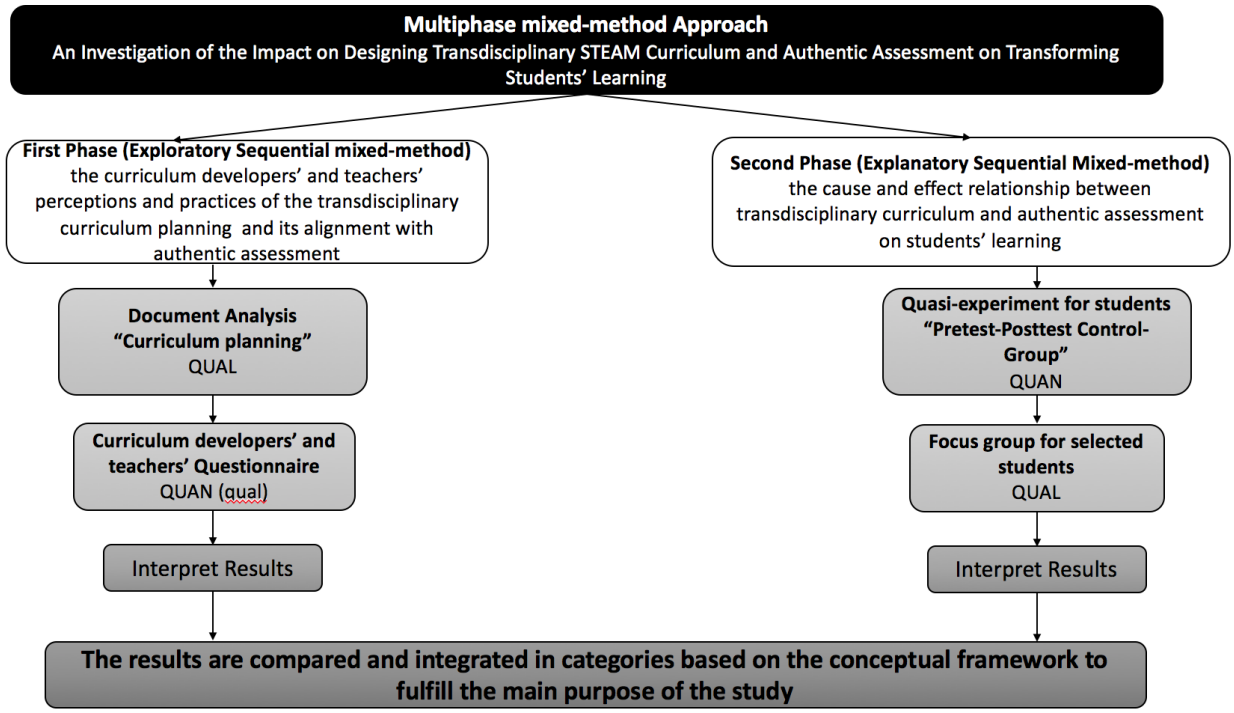

Figure (3.1): The multiphase mixed-method study design.

The multiphase mixed-method is used with two different phases that fulfill the main purpose of the study, illustrated below.

The first phase seeks to describe and understand the design model of the transdisciplinary curriculum in addition to the curriculum developers' and teachers' perspectives and perceptions. The results of this phase fulfill the first part of the main purpose of the study (designing transdisciplinary STEAM curriculum using authentic assessment). This phase is designed to be "Exploratory mixed-method" starting with a qualitative tool first (document analysis) then followed by a quantitative tool (curriculum developers' and teachers' questionnaire). As stated by Creswell (2014) the quantitative data is used to test the hypotheses or confirm the results of qualitative data.

The second phase seeks to find the cause-and-effect relationships between the transdisciplinary curriculum and authentic assessment on students' learning. This phase is used to fulfill the second part of the main purpose of the study (transforming students' learning). It is designed to use the "Explanatory sequential mixed-method" where the quantitative data was collected first using quasi-experiment (pretest-posttest control group) then followed by the qualitative tool using focus group discussions. The qualitative data is used to understand in depth the results of the quantitative data through selected participants. The integration of the results from first and second phase is used to fulfill the main purpose of the study (the impact of designing transdisciplinary STEAM curriculum using authentic assessment on transforming students' learning in a vocational institute in UAE). The following table explains the

organization of the study to understand the approach, instruments, participants and sampling used to address the research questions.

Research Question	Participants	Sampling	Instrument	Approach
How is authentic assessment planned in a transdisciplinary STEAM curriculum?	Three Engineering courses + graduation project (15 Lesson plans)	Extreme-case sampling	Document Analysis	Qualitative
What are the curriculum developers' and teachers' perceptions and practices in designing and planning a transdisciplinary STEAM curriculum?	Curriculum Developers, and Teachers (n1 = 51)	Convenience sampling	Questionnaire Open- & Closed-ended	Quantitative & Qualitative
What changes if any, do emancipatory, communicative, and instrumental learning have on transforming students' learning?	Grade 12 Students in Engineering Science Stream (n2 =80) Males = 40 Females = 40	One-stage cluster sampling	Questionnaire closed-ended items: Quasi-experiment "Pretest-Posttest Control Group"	Quantitative
How does the students' frame of reference vary after being exposed to the transdisciplinary course and authentic assessment?	Selected students 2 groups each with 6 students (n3 = 12)	Homogenous sample selection	Focus Group	Qualitative

Table (3.1): Summary of the organization of the study with research questions, approach and methods.

3.2 Site Selection

This study was conducted on two campuses of a governmental vocational institute in the United Arab Emirates UAE who are following the same system and curriculum. The main curriculum of this institute is designed to focus on the STEAM curriculum where the high school students have the option to choose from different streams created that involve: Health, Computer Science, Engineering Science, or Business. The curriculum chosen for this study is the Engineering Science stream courses with the graduation projects.

3.3 Population of the Study

The population is the entire aggregation of people the researcher chose for study (Johnson & Christensen, 2014). The participants of the study involve three different groups: curriculum developers, teachers, and high school students. The curriculum developers and

teachers consist of seventy individuals who form the whole population of the institute. The number of whole population of the high school students is 560 students. The participants selected for the study were eighty students for the quasi-experiment; and twelve students for the focus group. The sample were selected randomly (class sections) and non-randomly from each group of participants. One of the advantages of random selection is that it allows for generalizations to be made from sampling to population (Johnson & Christensen, 2014). This is due to the opportunity for every participant to take part in the study. However, some researches do not select random samples in order to control variables (Johnson & Christensen, 2014). Accordingly, different samples were selected randomly and non-randomly with different types that are illustrated below.

3.4 Samples Selection

The sample selected for the qualitative data in the study is a criterion-based selection where the selection of the sample is based on criteria set by the researcher (Johnson & Christensen, 2014). The sample selected for the document analysis is called "Extreme-case sampling" where the extreme of some characteristics are set and the samples selected accordingly from (Johnson & Christensen, 2014). The "extreme-case" sample is done in two stages. First, setting the questions that represent the extreme characteristics needed for the lesson plans from three courses and a graduation project. Then, select the lesson plans that meet all the criteria set for document analysis. The number of document analyses used was in total fifteen lesson plans selected from three courses and the graduation project.

The curriculum developers and teachers involved all the participants with a shared characteristic where all of them are teaching, designing and planning the courses in the Engineering Science cluster. The participants are curriculum developers and teachers from the following disciplines: English, Physics, Computer Science, Engineering and Mathematics. The target population is N1=70 and the sample selected non-randomly is "convenience sampling" where n1=51. The "convenience sampling" is to include people who are available, who volunteer, are willing to participate in the research study, or can be easily recruited (Johnson & Christensen, 2014). The convenience sampling might cause unclear data due to the selection of participants. According to Johnson & Christensen (2014), it is important for the researcher to describe the characteristics of the participants in their research studies and examine it. Accordingly, the demographic information used in the questionnaire aims to describe the characteristics of the participants. Then, the participants who were not fulfilling the criteria

have been excluded from the study. Participants who have shared characteristics where all of them are teaching, designing and/or planning the courses in the Engineering Science stream are all included in this study.

The target population of students are grade 12 students that form N2=560 students (260 are males and 300 are females) who had entered the Engineering Science cluster. The students' sample is selected equally from two campuses to form total n2=80. The sample selected is called "One-stage cluster sample" where two classes (boys and girls) from each campus were selected randomly to form an experimental group in one campus and control group in the other. The one-stage cluster sample is the clusters (classes) that are selected randomly from different clusters (Johnson & Christensen, 2014).

The sample selected for the focus group is called "Homogenous sample selection". The focus group researchers commonly use this procedure with a small homogenous group of six or seven participants to gain an in-depth understanding of how individuals in the group think about a topic (Johnson & Christensen, 2014). The sample selected is two homogenous groups from the experimental group only to form n3=12 in order to explain the changes in students' perceptions in more depth.

3.5 Instrumentation

The following sections describe the use and the purpose of the instrumentations. The instrumentations used in this study are the document analysis, curriculum developers' and teachers' questionnaire, students' questionnaire, and focus group discussions. The document analysis and the curriculum developers' and teachers' questionnaire are used in the first phase of the study while the students' questionnaire and the focus group discussions are used in the second phase of the study.

3.5.1 Document Analysis

Fraenkel, Wallen and Hyun (2014) defined document analysis as a technique used to study the behavior, practices and perceptions of participants in an indirect way through analyzing their documents. The document analysis has certain characteristics by which the descriptive information should be categorized (Fraenkel, Wallen and Hyun, 2014). It depends on the researcher to determine the categories before analyzing documents or afterwards (Fraenkel, Wallen and Hyun, 2014). In this research, the document analysis is done through a checklist prepared with the categories (Know, Do, and Be) that are based on the framework of the study. Fraenkel, Wallen and Hyun (2014) highlighted some objectives of document analysis

that are considered in this study and described. First, document analysis is used to obtain descriptive information about a topic (Lesson plans). It is used to formulate, organize, and make sense of a large amount of descriptive information into coded themes. It is used to validate the findings of the study where it is used with another method that is complementary to it. The document analysis is used to obtain useful information in dealing with educational problems. Finally, document analysis can be used to investigate possible relationships or test ideas. One of the important aspects that should be considered in order to locate relevant data is to analyze the relationship between contents that are aligned to the research objectives (Fraenkel, Wallen and Hyun, 2014). The sample selected for document analysis could be random, stratified, or cluster sample, depending on the purpose of the study (Fraenkel, Wallen and Hyun, 2014). In this study, the sample selected for document analysis is an extreme-cluster sampling where the lesson plans are selected from three courses and a graduation project that are considered to be clusters. The categories of document analysis should be explicit and clear to another researcher who can use them to examine the same material (Fraenkel, Wallen and Hyun, 2014). Regarding data analysis, there are different ways to analyze documents and interpret results, such as: counting, frequencies, descriptive statistics, or narrative descriptions (Fraenkel, Wallen and Hyun, 2014). It is stated that the end product of coding document analysis must be numbers such as frequencies (Fraenkel, Wallen and Hyun, 2014). Accordingly, the data analysis of the documents is interpreted in coded themes as well as calculated frequencies. According to Fraenkel, Wallen and Hyun (2014), there are some advantages and disadvantages of document analysis, as stated below. The most advantageous of the document analysis is that it is unobtrusive, where the documents are analyzed and not influenced by the participants' presence and without them being aware that it is being examined (Fraenkel, Wallen and Hyun, 2014). Document analysis is simple and economical compared to other methods in addition that it is not limited by time and space (Fraenkel, Wallen and Hyun, 2014). Regarding the disadvantages, it is limited to the recorded information that cannot demonstrate behaviors or skills (Fraenkel, Wallen and Hyun, 2014). Another main disadvantage is establishing validity where usually the interpretation of document analysis data assumes that what is clear to the researcher remains clear to others and what is unclear remains unclear to others (Fraenkel, Wallen and Hyun, 2014). The last disadvantage is that the interpretations that are gleaned from document analysis indicate the causes of a phenomenon rather than a reflection of it (Fraenkel, Wallen and Hyun, 2014).

The documents selected in this study are the lesson plans of transdisciplinary STEAM courses and graduation projects within the Engineering Science cluster. The sample used for

the document analysis is an "extreme-cluster" sample that aims to be selected based on criteria set from three courses and a graduation project. The first course is on the AutoCAD software that is essential for students to learn in this cluster. This course is used in most of engineering courses and is required for the completion of the graduation project. This course integrates the technology, engineering, arts, and mathematics with less focus on science concepts. It is a college level course that is taught in a vocational institute for grade 12 students. The second course is electrical principles and application that is considered to include integrated concepts of science (physics), technology and mathematics in the form of the engineering concepts. This course is taught to grades 11 and 12. The third course is the robotics course that integrates the science, technology, engineering, and art, with less focus on mathematics. The graduation projects are fully planned and designed by students with teachers' guidance. The aim of analyzing these documents is to understand and describe the design model used for the transdisciplinary courses that promotes students' transformational learning, in addition to the extent of considering students' involvement in the planning. A checklist has been prepared and categorized based on the framework of the study. It starts with essential questions that should be addressed in order to complete analysis of the documents and is followed by questions that are categorized into Know, Do, and Be. Each category has items with responses (yes, somewhat, and no), followed by the comment box to document the important data of the planning (see Appendix B).

The essential questions should be addressed before reviewing the document, where the answers should be to choose yes or no. The questions are categorized based on the backward design to involve components of three categories: desired outcomes, assessment criteria, and learning plan. The reason for this essential question is to be sure that the lessons are designed to align the desired outcomes to the assessment in order to suit the main purpose of the study that seeks to investigate the impact of designing a transdisciplinary STEAM curriculum using authentic assessments in a vocational institute in UAE. If any of those components does not exist, the lesson plan was excluded from the study. The next part of the document analysis is categorized based on Drake's model (2010) where the categories involve the Know, Do, and Be (KDB). The Know part involves questions related to students' previous knowledge, the level of knowledge used in planning, age-appropriateness, degree of subjects' integration, assessment design, and guided questions. Then, this part is followed by a box for general comments for recording any important findings. The Do part involves questions to understand the level of skills identified in the planning and the kind of assessments. Then, it is followed by a general comments box in order to record any important findings. The last part (Be)

involves the feedback and reflection from authentic assessments that is used for teaching and its impact on students' learning and the time represented for students' post-conference where they have the opportunity to discuss feedback and setting plans to improve. Finally, this part ends with a general comment box for recording any unexpected and important findings. The results from the document analysis were then confirmed using the curriculum developers' and teachers' questionnaire.

Wiggins and McTighe (2005) stated that the there are three main steps of the backward design which are: identifying the learning outcomes, assessment criteria, and instructional strategies. In other words, the lesson plans should be designed to involve three main steps: What do students need to know (Knowledge)? What they are able to do (Skills)? Then, plan for the instructional strategies and learning experiences to build the lesson. Biggs (1996) stated that the constructive alignment that is based on the backward design can be used as a tool to design and evaluate lesson plans. The constructive alignment theory is used as an outline of the document checklist as it is designed based on the framework of the study. It is based on the constructivism theory that aims to encourage and support students' construction of their knowledge instead of being receivers of information from teachers' instructions (Tran, Griffin, & Nguyen, 2010). Rust (2002) highlighted the importance of the alignment between what students are intended to learn and what is being taught, in addition to including varieties of authentic assessments that enhance students' learning. As a result, authentic assessment is used for improving learning not to assess learning. A study of Frazer and Bosanquet (2006) stated that the constructive alignment theory is an important tool in designing the curriculum in order to ensure the high quality of teaching and learning. Another study, of Treleaven and Voola (2008,) used the constructive alignment as a tool to integrate the students' attributes with the intended outcomes, learning tasks and activities, and assessment tasks by collecting data of students' feedback. On the other hand, the results of a case-study design of Leigh, Rutherford, Wild and Hynes (2013) strongly emphasizes the use of constructive alignment as a tool to measure the leadership development and students' achievement. A study of Borrego and Cutler (2010) aimed to use the constructive alignment theory in designing an integrated curriculum of science and engineering education. Finally, many studies used the constructive alignment theory in designing curriculum and its impact on students' learning (Wang, Cheung, Wong & Kwong, 2013; Larkin & Richardson, 2013). While analyzing lesson plans many factors are considered; these are known as dimensions of curriculum, and comments have been taken. Leithwood (1981) highlighted nine dimensions of the curriculum: platform, objective, student

entry behaviors, assessment, tools and procedures, instructional materials, learner experiences, teaching strategies, content and time.

3.5.2 Curriculum Developers' and Teachers' Questionnaire

The curriculum developers' and teachers' questionnaire was used to address the second question of the study: What are the curriculum developers' and teachers' perceptions and practices in designing and planning a transdisciplinary STEAM curriculum? It aims to describe statistically the curriculum developers' and teachers' practices through the closed-ended items; and investigates their perceptions in more depth through open-ended questions. The questionnaire is designed based on the framework of the study to focus on the Know category (curriculum and assessment design) and Do category (skills developed from emancipatory, communicative, and instrumental learning) using closed-ended items and followed by three open-ended questions (see Appendix C). The participants who are involved in this study are the curriculum developers and teachers. The sample is a convenience sampling that aims to select the participants who have shared characteristics and are available and willing to share in the study.

The questionnaire consists of three main sections: Demographic information, closed-ended items, and open-ended items. The demographic information consists of six closed-ended questions that collect some information about the participants: Level of education, gender, position, years of experiences, specializations, and professional development programs. The second category is closed-ended items and consists of sub-sections: curriculum and assessment design; emancipatory learning (critical thinking and independent learning skills); instrumental learning (creativity and innovation and problem-solving skills); and communicative learning (communication, collaboration, and self-direction skills). Finally, the last section in the questionnaire consists of three open-ended questions that ask curriculum developers and teachers about the impact of feedback given to students; challenges in designing transdisciplinary lessons and authentic assessments; and the advantages of this kind of planning.

The second section of the questionnaire comprises the Likert-scale items that start first with curriculum and assessment design (Know) that involve thirteen items. This part asks the curriculum developers and teachers about their perceptions of the degree in designing and planning a transdisciplinary curriculum aligned to authentic assessments. The items in this section ask participants detailed questions about their perceptions in: shifting from STEM to

STEAM; relating a transdisciplinary curriculum to career goals; students' engagement and active learning; giving students feedback in a more motivational way; time taken for creating and grading authentic assessments; connection between contents; detailed instructions given; and indicators of students' attainment. This is followed by categories of the three types of learning (Do): emancipatory, instrumental, and communicative learning. The emancipatory learning, also known as reflective learning, involves seven items about the degree of developing critical thinking and independent learning skills with students. The items in this part ask participants about their perceptions of how students gather, evaluate, and synthesize information; reflect on their own learning; think logically; students' setting their own targets; and being independent learners. The instrumental learning involves six items that ask about the degree of developing creativity and innovation and problem-solving skills with students. The items in this part of the questionnaire focus on asking participants about their perceptions of where students can: think divergently and generate new ideas; use an extensive range of subjects' techniques; be open to challenges, difficulties and risk-taking; complete their research; solve complex problems; and use technology as a tool. Then, the communicative learning category involves ten items that ask about the degree of developing communication, collaboration, and self-direction skills with students. The items in this part of the questionnaire ask participants about their perceptions of viewing students: communicating; organizing their thoughts; using a wide range of modern technology to facilitate communication; work productively with others; arguing points of view; guide each other; plan and define their work; take responsibility and make decisions to resolve issues.

The results of the questionnaire confirm or disconfirm the results of document analysis by investigating curriculum developers' and teachers' perceptions and practices. The questionnaire is designed to use a five point Likert-scale (5=strongly agree, 4=agree, 3=neutral, 2=disagree, and 1=strongly disagree). Cohen et al. (2007) stated that the Likert-scale is a kind of ordinal data. Ordinal data seeks to indicate orders of responses (Cohen et al., 2007). The ordinal data used is a non-parametric data as the characteristics of the population are known (Cohen et al., 2007). Descriptive statistics is used to describe and present data, which includes: the mean (the average score); variance (a measure of how far scores are from the mean); standard deviation (a measure of range of scores calculated as the square root of the variance); and frequency of responses in percentage (Cohen et al., 2007).

Johnson and Christensen (2014) defined the questionnaire as a self-reported data collection that is used to gain information about participants' thoughts, feelings, beliefs, values, practices, and perceptions. The questionnaire can be used to collect quantitative, qualitative, or

mixed data (Johnson & Christensen, 2012). It is significantly important to note that the content and organization of a questionnaire are aligned with the research objectives and questions (Johnson & Christensen, 2012). Fraenkel, Wallen and Hyun (2014) stated that closed-ended items in questionnaire are directly to the point and more focused than open-ended questions. However, open-ended questions enable participants to write their perceptions in their own words in order to explain and qualify their responses and avoid limitations (Cohen, et al., 2007). Accordingly, the curriculum developers' and teachers' questionnaire is designed to include closed-ended items with two sections while the last section involves three open-ended questions in order to provide participants the opportunity to explain their perceptions.

Johnson & Christensen (2012) highlighted some principles that are important to consider while constructing the questionnaire. First, the questionnaire should be aligned with the research objectives by carefully reviewing the existing research literature as well as any related instruments that can be used for the same research. Second, it is significantly important to understand the participants and know how they think and view things in order to design a questionnaire that is suitable for their age and capability. It is also important to use a natural and familiar language that is understandable to participants. Questionnaire items should be precise, clear, and relatively short in order to avoid stress and confusion for research participants. One of the main principles is to avoid leading questions that suggest a certain answer. Also, loaded questions that contains emotionally charged words with positive and negative reactions should be avoided. In addition, avoiding double-barreled questions that combine two or more issues, in order to get specific responses for each issue. Negative words should be avoided so as not to affect participants' responses. Determine whether open-ended or closed-ended questions to be included is another principle where the purpose of the study will guide the researcher to decide whether to use quantitative, qualitative, or mixed questionnaires. Another principle is aiming to use mutually exclusive response that do not overlap and exhaustive responses that include all possible responses. The rating scale used in this questionnaire is a Likert-scale with five fully anchored points. The fully anchored point is the description written on each scale (Johnson & Christensen, 2012). One of the important principles is using multiple methods when measuring abstract constructs (Johnson & Christensen, 2012). Accordingly, the questionnaire is used after document analysis in order to investigate to what extent the transdisciplinary curriculum is aligned with the authentic assessments. The questionnaire is used to learn about the curriculum developers' and teachers' perceptions in designing the transdisciplinary curriculum. The contingency question is another principle that directs participants to different follow-up questions (Johnson & Christensen,

2012). This has been considered while designing the questionnaire where the questionnaire was created on a web survey called "Question Pro" that contains contingency questions. Finally, the pilot study is the most important principle that aims to know if the questionnaire operates properly before using it in a research study (Johnson & Christensen, 2012).

3.5.3 Students' Questionnaire

The students' questionnaire aims to address the third question of the study: what changes, if any, does emancipatory, communicative and instrumental learning have on transforming students' learning? The students' questionnaire is used for conducting a quasi-experiment "pretest-posttest control group" that aims to measure the cause and effect of the treatment (emancipatory, instrumental and communicative learning) that are set as independent variables on transforming students' learning (dependent variable). It starts with a demographic section that asks students about their gender, age, and proficiency level in each of the STEAM subjects. The second section of the questionnaire includes the closed-ended items and is categorized based on the "Do" part of the framework of the study that involves three independent variables: emancipatory, communicative, and instrumental learning (see Appendix D) using Likert-scale items. The emancipatory learning involves six items that asks students about their experiences, beliefs, and reflection. In this part, students were asked questions about their perspectives of viewing themselves to: recognize problems; define constraints; set clear and challenging targets; reflect on their own beliefs; and reflect and evaluate their own learning and outcomes. The instrumental learning involves six items that asks students about the extent of experiencing different skills. Students think about their perspectives and points of view in answering questions about: using an extensive range of subjects' techniques; open to challenges, difficulties and risk-taking; using their knowledge to identify and define complex problems; complete a research; and defend their solutions. The communicative learning part is involving seven items that ask students about the extent of communicating and collaborating with their peers. The items in this part ask students about their perceptions of: communicating information accurately and clearly; using a wide range of technologies as means of communication; working productively with others; planning, defining and working towards goals; argue a point of view respectfully; and connecting ideas with their peers.

The independent variable is an input variable that causes a particular outcome (Cohen, Manion & Morrison, 2007). The independent variables in the students' questionnaire are the

three types of learning: emancipatory, instrumental, and communicative learning. On the other side, the dependent variable is the outcome variable that is caused as a result of independent variable input (Cohen, Manion & Morrison, 2007). The dependent variable here is the change in students' frame of references that involves: mindsets, habits of minds and perspective transformation. The operational definitions of the variables are stated below.

- The emancipatory learning (Independent variable): is the type of learning known as reflective learning. It is the cognitive domain where students develop their critical thinking and independent learning skills.
- The instrumental learning (Independent variable): is the type of learning that represents the psychomotor domain where students develop creativity and innovation and problem-solving skills.
- The communicative learning (Independent variable): is the type of learning that lies in the affective domain where students are communicating and collaborating through their learning processes.
- Students' frame of reference (Dependent variable): is the students' habits of mind, mindsets, and perspective transformation.

The independent variables occur due to exposing students to the authentic assessment tasks within transdisciplinary STEAM curriculum that require them to be engaged in the three types of learning (emancipatory, instrumental and communicative learning). The organization where the study is conducted has seven campuses in UAE that follow the same STEAM curriculum. The experimental group of students was selected from a different campus than the control group. On one side, teachers in the campus of the experimental group were trained on using the authentic assessment tasks. On the other side, neither the control group of students were exposed to the authentic assessment tasks nor teachers within the same campus trained on the use of authentic assessment tasks. They were exposed to the transdisciplinary curriculum without being involved in authentic assessment tasks. Teachers prepared different activities for students that uses formative assessments such as quizzes, observation and discussion.

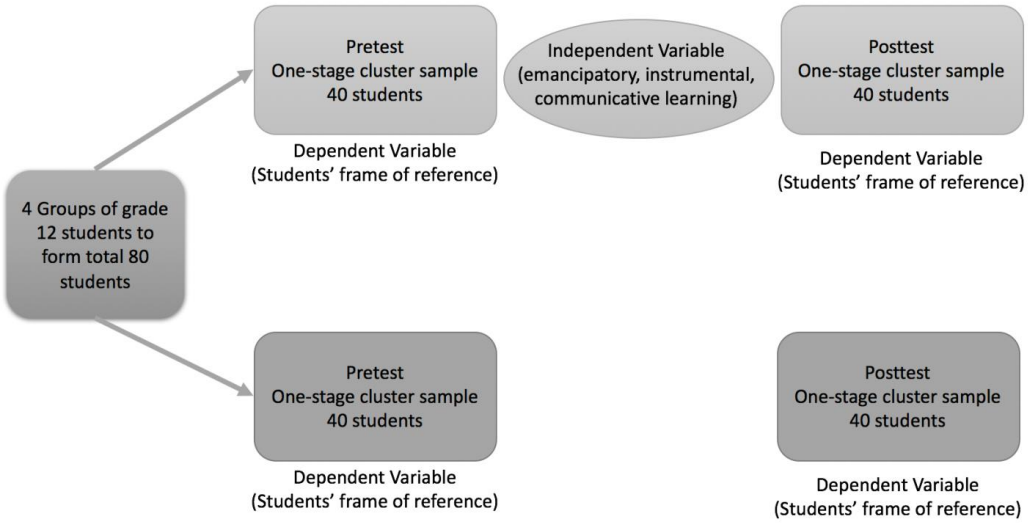

Figure (3.2): The Quasi-Experiment "pretest-posttest control group" using students' questionnaire.

Stuckey, Taylor and Cranton's (2013) study used a survey as a quantitative tool in order to measure the impact on transforming students' learning through the three types of learning suggested by Haberman (1971) (emancipatory, communicative, and instrumental learning). The questionnaire is designed with two sections: outcomes of transformative learning, and processes of learning. The results of the study emphasized the change in students' perspectives after being exposed to the three types of learning (Stuckey, Taylor and Cranton, 2013).

The questionnaire and survey are tools used to learn the opinions of a large group of people on a particular topic (Fraenkel, Wallen & Hyun, 2014). Fraenkel, Wallen and Hyun (2014) stated that the data collected from the survey at different points of the study is a longitudinal survey. The purpose of the pre- and post questionnaire is to measure the change in students' frame of reference after being exposed to the link between the transdisciplinary curriculum and authentic assessment (emancipatory, instrumental, and communicative learning). This is called the panel study where the same sample of students are having the questionnaire at different times to track the changes during the course of the survey (Fraenkel, Wallen and Hyun, 2014). The first step of designing the questionnaire is defining the problem and align the questionnaire items to the objectives of the study by reviewing the literature related to the study (Fraenkel, Wallen and Hyun, 2014). Then, it is important to identify the participants of the study and how the sample are selected (Fraenkel, Wallen & Hyun, 2014). In this study, the participants are grade 12 students and the sample is randomly selected. The students' questionnaire is created on a web survey called "Question Pro" that has the advantage of easy access to the questionnaire (Fraenkel, Wallen & Hyun, 2014). The students'

questionnaire is developed to be used as pretest and posttest with the same items that are designed for a quasi-experiment with control and experimental groups using a five point Likert-scale (5=strongly agree, 4=agree, 3=neutral, 2=disagree, and 1=strongly disagree). Cohen, Manion and Morrison (2007) mentioned that the Likert-scale is ordinal data that is considered to use a non-parametric test. It is less complicated and gives valuable feedback to the researcher about results (Cohen, Manion & Morrison, 2007). The closed-ended items have many advantages and disadvantages that were stated by Fraenkel, Wallen and Hyun (2014). Regarding the advantages, it enhances consistency of responses across respondents; is easy and fast; and more popular with respondents. For the disadvantages, it may limit the breadth of respondents; take more time to create; and require more questions to cover the topic. Accordingly, the focus group discussions using open-ended questions followed the post questionnaire in order to avoid the disadvantages of closed-ended items included in the questionnaire. The questionnaire is piloted for validity and reliability concerns. In addition, it is sent to experts for content validity. The quasi-experiment may form a threat of internal validity because the sample are not randomly selected (Johnson & Christensen, 2014). Accordingly, this has been treated in this study by selecting a one-stage cluster sample, which means there are two clusters that are selected randomly from a group of clusters in order to avoid the threat of internal validity. The students' questionnaire is used as pretest and posttest in a quasi-experimental design. Experimental research is a powerful research approach to find the cause and effect relationships among variables (Fraenkel, Wallen & Hyun, 2014). In addition, the most effective way to achieve internal validity is to include a control group and select the sample randomly (Johnson & Christensen, 2014) which are considered in this study. The experimental group is the group that receives the experimental treatment conditions while the control group is the group that does not receive any treatment (Johnson & Christensen, 2014). The pretest – posttest control group design is research that administers the posttest to two groups randomly after both have been pretested and one of the groups has been administered the experimental treatment conditions (Johnson & Christensen, 2014). The quasi-experiment approach is an experimental situation that does not provide full control on variables because participants are not selected randomly (Creswell, 2014). However, in experimental study, there is more control on variables than any other type in addition to minimizing the threats of internal validity (Fraenkel, Wallen & Hyun, 2014).

3.5.4 Focus Group Discussion

The focus group discussion is conducted after the quasi-experimental research in order to narrow the lens and understand the transformation of students' opinions through open-ended reflective questions that are suggested by Cranton (1994). Johnson and Christensen (2014) stated that the focus group is aiming to understand the group's perceptions and impressions of products or programs. Johnson and Christensen (2014) stated that the focus group is a type of interview where the moderator is leading a small group of participants (6 to 12) and gives them opportunities to discuss the questions while listening to the views of others. The focus group is used as a complement of the quantitative data (students' survey) where it provides in-depth information in a relatively short period (Johnson & Christensen, 2014). As the quasi-experiment is conducted over a duration of three months, it is not enough to track major changes in students' perspectives, however the use of a focus group can explain in depth the changes that have occurred in students' perspectives. The focus group discussions are used for multiple purposes such as: stimulating new ideas and creative concepts; diagnosing the potential for problems with any new program; generating impressions; and understanding how participants feel and talking about the phenomenon of interest (Johnson & Christensen, 2014). The participants in a focus group should be selected purposefully to ensure having homogenous groups discussing the same kind of information that interests them (Johnson & Christensen, 2014). In this study, the experimental group are purposefully participating in the focus group. However, students from the experimental group were selected randomly where students in this group have shared characteristics. The open-ended questions in the focus group should all be covered and there should be space for adding or modifying questions to run the discussion successfully (Johnson & Christensen, 2014).

The open-ended questions suggested by Cranton (1994) are reflective questions on content, process, and premise within each type of learning (emancipatory, communicative, and instrumental). The indicative outcomes that show transformation of students' learning occur by Cranton's (1992) framework of three types of change: change in assumptions, change in perspective and change in behavior. Boyd (1989) highlighted that the outcomes of transformative learning include a change in itself. The change in assumptions occurs through the reflective questions on content within each type of learning (Reis, 2005). The change in perspective occurs through the reflective questions on process within each type of learning (Reis, 2005). Finally, the change in behavior occurs through the reflective questions on premise within each type of learning (Reis, 2005). The content question is a question that starts by what,

process starts by how, and premise question starts by why. In the emancipatory section the questions are asking students about their assumptions, how change is obtained, and why. The instrumental learning questions are asking students about the cause of change, how they know, why they feel it is important. Finally, the communicative learning questions are asking students about others' opinions of change, how change is socially influenced, and why they believe in this change. A study by Fullerton (2010) who used a mixed method design, stated that the impact of students' transformational learning requires qualitative data with interviewing students in an interview using open-ended questions that are based on Cranton's (1992) framework. The results of this study showed the change in students' perspectives and habits of minds using Cranton's (1994) reflective questions on content, process, and premise (Fullerton, 2010). In addition, Fullerton (2010) used a survey tool as quantitative data in order to learn about students' perceptions. Another study by Saravanamuthu (2015) used the same reflective open-ended questions of Cranton (1994) in learning about the impact on students' transformational learning through an interview. As a result, the focus group discussion is designed to be complementary to the quasi-experiment as it seeks to understand the phenomena in depth (see Appendix E).

3.6 Data Analysis

This study is designed to use multiphase mixed-method that has two different phases and hence collects different types of data that require a variety of data analysis techniques, as explained in the section below. The data of first phase of the study (exploratory sequential design) and the data of the second phase of the study (explanatory sequential design) are collected concurrently. However, results from each phase are analyzed and interpreted separately. Then, the results of the two phases (exploratory sequential method and explanatory sequential design) are compared and integrated to address the main purpose of the study. The first phase is the curriculum developers' and teachers' perceptions and practices about designing the transdisciplinary curriculum using authentic assessment, which is supporting and confirming the second phase results from the curriculum developers' and teachers' perspectives.

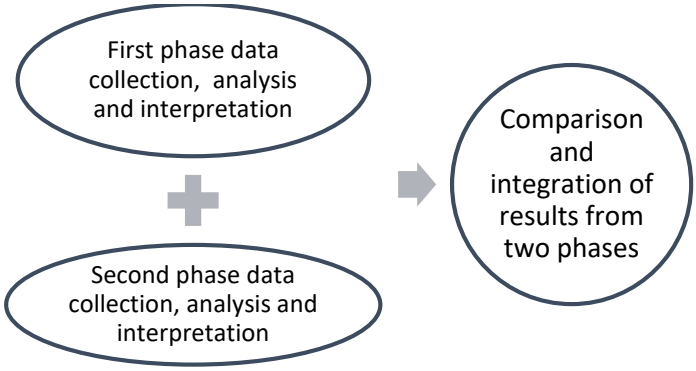

Figure (3.3): The first and second phases' data collection, analysis, and interpretation.

The first phase of the study is "Exploratory Sequential Mixed-method" where it starts first by exploring with qualitative data and analysis. Then, the use of the findings in the quantitative data collection that follows, obtain participants' perceptions to confirm or disconfirm the qualitative data. This strategy aims to determine if the qualitative results can be generalized (Creswell, 2014). This is because the quantitative data is built based on the qualitative data results in order to confirm participants' perceptions with the document analysis and generalize the findings.

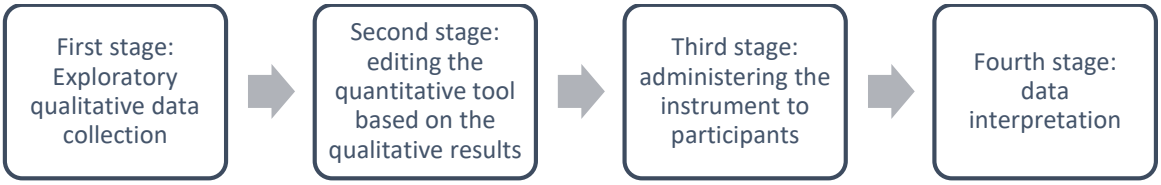

Figure (3.4): First phase of the study shows Sequential Exploratory Design (Qualitative → Quantitative).

In this phase, the qualitative data from document analysis is collected, analyzed, and interpreted in the first stage. Then, the results are used to edit and inform changes on the curriculum developers' and teachers' questionnaire that was designed earlier based on the categories used in the document analysis. The third stage in this phase is to administer the questionnaire to the curriculum developers and teachers. The responses of the curriculum developers' and teachers' questionnaire are collected through a survey website called "Question Pro", then it is analyzed using the Statistical Package for Social Sciences (SPSS) software. The quantitative data of the curriculum developers' and teachers' questionnaire is analyzed using descriptive statistics to find mean, standard deviation, and frequency of responses. The quantitative result is used to confirm or disconfirm participants' perceptions about the results of document analysis. The data from the qualitative results is interpreted and

informs what changes are to be made on the curriculum developers' and teachers' questionnaire. Then, it is followed by interpretation of the quantitative data using descriptive statistics. At a later stage, the conclusion of the results in phase one is merged, interpreted, and kept for the results of the second phase. The curriculum developers' and teachers' questionnaire is piloted for validity and reliability concerns.

The second phase is the "Explanatory Sequential Mixed-method" that lies in collecting the quantitative data first then the qualitative data. The quantitative data is collected using quasi-experiment (pretest-posttest control group). The pretest is conducted at the beginning of the term for control and experimental groups followed by the treatment (emancipatory, communicative, and instrumental learning) for the experimental group, and the posttest was conducted by the end of term for both groups. Teachers in the campus of experimental group participated in a professional development program about the use of authentic assessment in designing a transdisciplinary curriculum conducted by the curriculum developers. Johnson and Christensen (2014) stated that the use of experimental and control groups in quasi-experiment is more powerful than one group only in order to understand the cause and effect of the independent variables (emancipatory, communicative, and instrumental learning). The dependent variable is the change in students' frame of reference about their learning.

The students' pretest and posttest questionnaire is given to them through a survey website called "Question Pro" then it is analyzed using the SPSS software. The data used is ordinal data using five points Likert-scale items. The ordinal data is non-parametric data however test results considered to be parametric data as it is more powerful and enable the researcher to compare sub-populations with a whole population (Cohen, Manion & Morrison, 2007). In addition, it was stated that the parametric test can be used with ordinal data when the population of both experimental and control groups have the same variance (Awang, Afthanorhan & Mamat, 2016). Furthermore, it was stated that when a parametric data (students' results) used with non-parametric data (Questionnaire results), the tests used should be parametric test (Cohen, Manion & Morrison, 2007). In addition, the parametric test can be used with ordinal data when the population is not large sample (Awang, Afthanorhan & Mamat, 2016; Carifio & Perla, 2008; Wadgave & Khairnr, 2016). The results of the students' questionnaire in the quasi-experiment is analyzed using inferential statistics to find t-test, ANCOVA, multiple regression, and one-way ANOVA. The multiple regression is used in anticipating the effect of independent variables on a dependent variable especially when using three or more independent variables as is the case in this study (Cohen, Manion & Morrison, 2007). The multiple regression test is used to predict the changes that happen to the participants

(Cohen, Manion & Morrison, 2007). It is multiple linear regression model that includes the polynomial regression model where the relationship between the dependent variable and independent variable is curvilinear (Shalab, 2016). The linear regression model $\gamma = \chi\beta + \varepsilon$ includes the polynomial regression model (Shalab, 2016). In addition, the t-test is used to measure the differences between the means of two groups (experimental and control groups) with regards to the three independent variables (emancipatory, communicative and instrumental learning) (Cohen, Manion & Morrison, 2007). The one-way ANOVA is used to determine whether there are any significance differences between the means of control and experimental groups (Cohen, Manion & Morrison, 2007). The ANCOVA is used to test the interaction effects of the independent variables on the dependent variable while controlling other continuous variables (covariate) (Cohen, Manion & Morrison, 2007). The quantitative data is analyzed and interpreted then, it is followed by the qualitative data to explain the results and narrow the scope of the quantitative data into the change of students' frames of reference. The quantitative data results usually inform the types of participants involved in the second stage of the qualitative tool (focus group discussion) and the types of questions. The students' questionnaire is piloted for reliability and validity concerns.

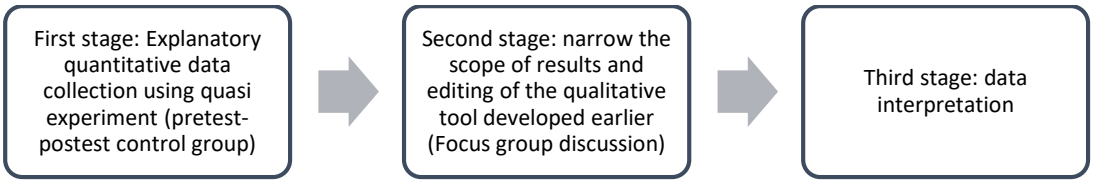

Figure (3.5): Second phase of the study shows Sequential Explanatory Design (Quantitative → Qualitative).

The figure shows the sequence of analyzing data where the results of the quantitative stage are interpreted first, followed by the results of the qualitative stage. Then, the qualitative results are used to narrow the scope of quantitative data and explain the quantitative results. The conclusion of the results is interpreted and merged with the results of both data.

3.7 Pilot Study

Reliability is defined as the consistency and stability of the results while validity is defined as the ability to measure what it is intended to measure (Johnson & Christensen, 2014). According to Fraenkel, Wallen and Hyun (2014), anonymous surveys and questionnaires meet the reliability as they encourage participants to be honest in responses. The instruments of this study are designed to be anonymous. A pilot study of the questionnaires is conducted for

validity and reliability purposes as recommended by Fraenkel, Wallen and Hyun (2014). The average inter-item reliability is a subtype of internal consistence reliability that is obtained to determine the correlation coefficient for each pair of items and the average of all these correlation coefficients is known as inter-item coefficient (Phelan & Wren, 2005). The average inter-item correlation which is a subtype of internal consistency reliability using Cronbach's Alpha test is measured in this study. The Cronbach's Alpha test is to show the level of consistency between the students' questionnaire items as well as curriculum developers' and teachers' questionnaire items (Cohen, Manion & Morrison, 2007). Cohen, Manion and Morrison (2007) mentioned the following alpha coefficient "> 0.9 very highly reliable; 0.80-0.90 highly reliable; 0.70-0.79 reliable; 0.60-0.69 marginally reliable; and <0.60 unacceptable".

3.7.1 Reliability

After piloting the students' questionnaire and curriculum developers' and teachers' questionnaire, a few changes are applied. The students' questionnaire was piloted with 84 students of grade 12 in another school. The reliability result of Cronbach's Alpha test = 0.918 which indicates that the questionnaire items are very highly reliable and consistent, with a total of 18 items (see Appendix F). In order to guarantee reliability, the correlation coefficient should be 0.05 or higher (Cohen, Manion & Morrison, 2007). The inter-item correlation matrix in the students' questionnaire shows high level of correlation at significant level of $\alpha > 0.05$ and the relations between the variables are positive (see Appendix F).

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha based on Standardized Items	N of Items
0.918	0.920	18

Table (3.2): Reliability Test Result of Students' questionnaire.

In addition, the teachers' questionnaire was also piloted as with 32 teachers in another school. Again, some modifications are done with a few words changed. The reliability result of Cronbach's Alpha test=0.901 which indicates that the questionnaire items are very highly reliable and consistent (see Appendix G). The reliability is guaranteed when the correlation coefficient is equal to 0.05 or higher (Cohen, Manion & Morrison, 2007). The inter-item correlation matrix in the curriculum developers' and teachers' questionnaire is high at

significance level of $\alpha > 0.05$ and there are positive relations between variables (see Appendix G).

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha based on Standardized Items	N of Items
0.901	0.97	32

Table (3.3): Reliability Test Result of Teachers' Questionnaire.

3.7.2 Validity

There are several types of validity such as: internal, external, construct, and statistical conclusion where the study can meet some or all of them (Creswell, 2014). The internal validity is the threats within experimental procedures, treatment, or experiences in the research (Creswell, 2014). This study has two phases of mixed-method that reduces the threats of internal validity. The participants should be randomly selected so that characteristics have the probability of being equally distributed which is considered a selection threat in internal validity (Creswell, 2014). The curriculum developers' and teachers' sample is selected as convenience sampling while for students, a one-stage cluster sample is randomly selected. One of the disadvantages of quasi-experiment is that the experimenter cannot create groups for the experiment (Creswell, 2014) however, the students' sample in this study is a cluster sample where the population is all students in the Engineering Science stream for seven campuses. Two campuses were selected for the study: the first campus was considered as the control group (2 classes) and the second campus is the experimental group (2 classes). The sample selection is randomly assigned from each group.

Another threat of internal validity is called maturation which implies in selecting participants to be as similar as possible (Fraenkel, Wallen and Hyun, 2014; Creswell, 2014). Curriculum developers and teachers have similar characteristics in that they are all involved in designing and planning the same transdisciplinary courses. Furthermore, grade 12 students were selected as participants of the study with the same age group. In order to avoid diffusion of treatment, the two groups need to be as separate as possible (Creswell, 2014; Johnson & Christensen, 2014). Accordingly, the control group is in one campus and the experimental group is in another campus in order to avoid the diffusion of treatment as the institute system has the same curriculum. The instrument of the pretest and posttest is the same instrument which met what Creswell (2014) states about the instrumentation threat of internal validity. The quantitative instruments are sent to experts in order to take their judgments on the tools

which is called “content-related evidence” (Fraenkel, Wallen & Hyun, 2014) that satisfies validity.

The external validity threats arise when experimenters draw incorrect inferences or when the bias occurs in having qualitative data (Fraenkel, Wallen & Hyun, 2014). This is avoided in the design of the study as in the first phase the qualitative data are confirmed and validated using quantitative data where the results can be generalized. In the second phase, the quantitative data is followed by qualitative data in order to understand the important changes occurred with the students. Studying the phenomena in its natural setting is an advantage of quasi-experiment that satisfies the external validity (Fraenkel, Wallen & Hyun, 2014). The experimental designs allow drawing conclusion about the causal relationship between and among variables while the descriptive designs provide a complete picture of what is occurring (Fraenkel, Wallen & Hyun, 2014).

The mixed-method research meets several types of validity called “legitimation”, such as: meta-inference, inside-outside validity, paradigmatic, commensurability mixing validity, weaknesses minimization, sequential, and sample integration validity (Johnson & Christensen, 2014). These legitimations are considered in this study. The meta-inference validity is the inference of the conclusion that builds from integrating qualitative and quantitative results which is considered in this study. The inside-outside validity is the extent of understanding and presenting the emic (participants’ viewpoints) and etic (researcher viewpoint). This was met in analyzing the results and the discussion of the study. The paradigmatic is the degree in which the researcher explains the philosophical beliefs about the research through integrating qualitative and quantitative data. This is designed in this study where the explanatory sequential and exploratory sequential methods are designed to fulfill the main purpose of the study. Added to that is the commensurability that allows the researcher to switch between the lens of qualitative and quantitative methods; decreasing weaknesses of both methods and increasing the strengths of mixing two methods; and the sequential that allow for addressing any effect from the ordering of qualitative and quantitative methods. Finally, is the sample integration where the ability to generalize data and make meta-inferences from mixing samples is considered.

3.8 Ethical Considerations

Approval for conducting the study was sought in two campuses for the experimental and control groups. Initial approval from the Ethics Advisory Committee of the British

University in Dubai was obtained. This was followed by official approval from the organization that manages the vocational institutes where the study is conducted to access the research sites. Official permission from the participants and organization was taken, which are considered as ethical issues when reliable and valid data are collected (Cohen, Manion & Morrison, 2007). In order to increase the trustworthiness of the qualitative data collected, the participants' approval is considered before conducting the study. Full information is a type of ethical consideration where the participants have the right to know and understand the purpose of the study (Cohen, Manion & Morrison, 2007). However, if the researcher is not sure about the investigation of the study, in this circumstance the consent form has to be applied (Cohen, Manion & Morrison, 2007). Based on that, participants and organization are aware of the purpose of the study through the informed consent form that is given to them. Voluntarism is another type of ethical consideration that implies the freedom of participants to participate in this study (Cohen, Manion & Morrison, 2007). Accordingly, participants had the choice to participate in the study as all instruments are anonymous. In addition, the convenience sampling is used to select the participants from curriculum developers and teachers that aims to include people who are available, volunteer, are willing to participate or can be easily recruited. Accordingly, a description of the participants' characteristics has been formed through the demographic information of the questionnaire. Finally, comprehension is an ethical consideration that refers to the fact that participants should understand the nature of the research even if it is complicated (Cohen, Manion & Morrison, 2007). As a result, participants were provided with a fair explanation of the procedures and purpose of the research. A description of any expected risk has been explained and instructions are provided that refers to withdrawing consent and the right to not continue in the research. In addition, benefits that might derive from the research are explained and participants have the opportunity to ask questions about any aspect of the research. An important aspect of ethical consideration is to keep the work visible and to remain open for any suggestions that will benefit the research (Cohen, Manion & Morrison, 2007). According to Barrett (2006), the recruitment or agreement of participants depend mainly on the approval of key individuals or "gatekeepers". In order to avoid the practical ethical issues, a deal was set with the principals of the school who considered to be the gatekeepers. The deal was to provide free training for the participants of teachers and curriculum developers on the ways of using authentic assessment tasks in transdisciplinary SETAM curriculum. Another aspect of the practical ethical consideration is checking the sample size and the availability of participants who are required for the study (Barrett, 2006). Accordingly, the sample size of curriculum developers and teachers were

raised from 25 participants to 51 participants in order to ensure sufficient data that is collected from a large enough sample to be able to generalize the results.

The positionality is the position that the researcher has chosen to adopt within a given research study in relation to: the subject, the participants, and the research context and process (Savin-Baden & Major, 2013). Following the pragmatic philosophy ensures that there is no bias toward one type of research and that the approach used is wide-ranging and eclectic. As a result, the researcher positionality is insider-outsider who consider the emic (participants views) and etic (researcher view).

The following chapter reports the data analysis of the two phases of the study where each phase is followed by a summary of the results.

Chapter Four: Data Analysis and Results

In this chapter, the data collected is analyzed and interpreted. The study has two different phases, and each phase has its own data analysis and interpretation. The main purpose of the study is aiming to investigate the impact of designing a transdisciplinary STEAM curriculum using authentic assessment on transforming students' learning in a vocational institute in UAE. The purpose of the first phase of the study is to describe the practices and perceptions of the curriculum developers and teachers in planning, designing, and aligning the transdisciplinary STEAM curriculum to authentic assessment. The first two questions in the study are used to fulfill the purpose of the first phase that will address part of the main purpose of the study (the design of the transdisciplinary curriculum using authentic assessment). This phase is "exploratory sequential mixed-method" where qualitative data is collected first using document analysis. The results are interpreted and used to inform the quantitative tool (teachers' questionnaire). Then, the quantitative data is collected and analyzed using a curriculum team's questionnaire. The results of each set of data are analyzed and interpreted separately. Then, it is integrated in the summary of the results.

The second phase of the study aims to investigate the impact of exposing students to the emancipatory, communicative and instrumental learning. The third and fourth questions of the study were used to address the purpose of the second phase which is considered to be the other part of the main purpose of the study (transforming students' learning). The second phase aims to use "explanatory sequential mixed-method" where quantitative data is collected, first using quasi experiment "pretest posttest control group" and followed by qualitative data using focus group discussion. The results of the quasi experiment are used to inform the qualitative tool (focus group discussion). Again, the results of each set of data are analyzed and interpreted separately. Then, the quantitative and qualitative results are integrated in the summary of the second phase results. A multiphase mixed-method benefits from a strong theoretical perspective (pragmatism) that provides a guiding framework for thinking about different aspects of the study across the multiple phases (Creswell & Clark, 2011). Based on Johnson and Christensen (2014), the "dialectic paradigm" is research that uses multiple paradigms and an integrated perspective that allows for the synthesizing back and forth of multiple perspectives needed in the research. Accordingly, the important results are not interpreted in the same order of phases, but are interpreted based on the important aspects of the study.

4.1 Students' Questionnaire Results

The students' questionnaire is used to address the third question of the study, which is: what changes, if any, do the emancipatory, instrumental, and communicative learning have on transforming students' learning? The participants are grade 12 students in an engineering science stream. The participants are 80 students (40 experimental and 40 control groups). The sample selected is a one-stage cluster sample. A quasi experiment "pretest posttest control group" is used. Inferential statistics, where overall analysis, one-way ANOVA, t-test, ANCOVA, and multiple regression, are used. The analysis of this section is interpreted in the following sequence: adequacy and equivalency of the experimental and control groups; the effect of the treatment (emancipatory, instrumental and communicative learning) on transforming students' learning (perspective transformation); anticipation of transforming students' learning; variances of students' frames of reference (focus group discussion). The adequacy and equivalency section includes one-way ANOVA that was run to determine if there are any differences between the means of experimental and control groups through the pretest given to them. The effect of the treatment section includes: the overall analysis, one-way ANOVA, ANCOVA, and t-test. The one-way ANOVA test was run to determine the multiple comparison between the pretest and posttest of the control and experimental groups with regards to the three types of learning (emancipatory, instrumental and communicative learning). The analysis of covariance (ANCOVA) is conducted to determine where the mean of the dependent variable is equal to the mean of independent variables that are called a treatment (emancipatory, communicative and instrumental learning) while statistically controlling the effect of other variables ta are not of primary interest (covariate). In addition, an independent samples t-test was run to determine if there were differences between the control group and experimental group. Finally, the paired t-test was run to determine the difference between the pretest and posttest within each group. The anticipation of transforming students' learning is done through the multiple regression test that was run to predict if there will be changes to students' learning due to being exposed to the emancipatory, instrumental, and communicative learning.

4.1.1 Experimental and Control Group Adequacy and Equivalency

The participants were eighty students in grade 12 students (four classes). The classes were randomly selected to form two groups. Accordingly, the data were collected from two classes of experimental groups (males and females) and two classes of control groups (males and females). An independent sample t-test was used to find if there are differences in responses of the pretest control group and pretest experimental group. Table (9) shows the mean and standard deviation of each group. Table (10) represents the independent sample t-test.

Group Statistics					
	Groups	N	Mean	Std. Deviation	Std. Error Mean
Emancipatory	Control Group	40	3.6750	.60264	.09529
	Experimental Group	40	3.2333	.77515	.12256
Instrumental	Control Group	40	3.5667	.48891	.07730
	Experimental Group	40	3.7042	.49569	.07838
Communicative	Control Group	40	3.5500	.79081	.12504
	Experimental Group	40	3.5714	.68703	.10863

Table (4.1): Comparison of descriptive statistics between pretest control group and pretest experimental group.

The results of the pretest control group in the emancipatory learning (3.67 ± 0.60) were not equivalent to the pretest experimental group (3.23 ± 0.77), a significant difference found where the mean difference of 0.441 at 95% confidence interval, $t(78) = 2.84$, $p = 0.006$ ($p<0.05$), however, $p>0.001$ as it is used as a convenient level to identify the highly significant results. The results of the pretest control group in the instrumental learning (3.56 ± 0.48) were found to be equivalent to the pretest experimental group (3.7 ± 0.49), no significant difference was found where the mean difference of 0.137 at 99.9% confidence interval, $t(78) = -1.249$, $p = 0.215$ ($p>0.05$). The results of the pretest control group in the communicative learning (3.55 ± 0.79) were found to be more than the pre-experimental group (3.57 ± 0.68), no significant difference was found where the mean difference of 0.021 at 99.9% confidence interval, $t(78) = -0.129$, $p = 0.897$ ($p>0.05$).

Independent Samples Test										
	Levene's Test for Equality of Variances			t-test for Equality of Means						
	F		Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Emancipatory	Equal variances assumed	4.966	.029	2.845	78	.006	.44167	.15524	.132	.750
	Equal variances not assumed			2.845	73.530	.006	.44167	.15524	.132	.751
Instrumental	Equal variances assumed	.044	.835	-1.249	78	.215	-.13750	.11008	-.356	.081
	Equal variances not assumed			-1.249	77.985	.215	-.13750	.11008	-.356	.081
Communicative	Equal variances assumed	.667	.417	-.129	78	.897	-.02143	.16563	-.351	.308
	Equal variances not assumed			-.129	76.506	.897	-.02143	.16563	-.351	.308

The mean difference is:
*Significant at 0.05 level
**Highly significant at 0.01
***Extremely significant at 0.001

Table (4.2): Comparison of independent sample t-test between pretest control group and pretest experimental group.

In addition, a one-way analysis of variance ANOVA was conducted to determine whether there is any significant difference between the means of three independent variables of the control and experimental groups, as shown below in table (11).

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Emancipatory	Between Groups	3.901	1	3.901	8.094	.006
	Within Groups	37.597	78	.482		
	Total	41.499	79			
Instrumental	Between Groups	.378	1	.378	1.560	.215
	Within Groups	18.905	78	.242		
	Total	19.283	79			
Communicative	Between Groups	.009	1	.009	.017	.897
	Within Groups	42.798	78	.549		
	Total	42.807	79			

Table (4.3): Comparison of one-way ANOVA between experimental and control groups within emancipatory, instrumental, and communicative learning.

The ANOVA table shows that $p>0.05$ which means that there are no significant differences between the means of the experimental and control groups. This means that the groups are equivalent. In the emancipatory learning, the data obtained was significant for the groups, $F(1, 78) = 8.094$, $p<0.05$. However, $p>0.001$ which is used as convenient level to show the extreme significant results. Regarding the instrumental learning, the data obtained was not significant for the groups, $F(1, 78) = 1.560$, $p>0.05$. For the communicative learning, the data obtained was not significantly different for the groups, $F(1, 78) = 0.17$, $p>0.05$.

4.1.2 The effect of the treatment on transforming students' learning

A one-way ANOVA was conducted to determine the differences between the pretest and posttest of the experimental group with regard to the three types of learning (emancipatory, instrumental, and communicative learning) as shown in the table below.

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Emancipatory	Between Groups	17.288	1	5.7625	7.926	.000
	Within Groups	56.712	78	.363		
	Total	74.000	79			
Instrumental	Between Groups	15.871	1	5.290	10.367	.000
	Within Groups	39.802	78	.510		
	Total	111.346	79			
Communicative	Between Groups	19.175	1	6.392	8.517	.000
	Within Groups	58.535	78	.750		
	Total	77.711	79			

Table (4.4): The one-way ANOVA that represents the differences between pretest and posttest experimental groups.

The data shows that $p<0.001$ which means that there are extreme significant differences between the means of the pretest and posttest of experimental and control groups. This means that there might be at least one test that is different than the others. In the emancipatory learning, the data obtained was statistically significantly different for the different tests obtained, $F(1, 78) = 7.926$, $p<0.001$. Regarding the instrumental learning, the data obtained was statistically significantly different for the different tests obtained, $F(1, 78) = 10.367$, $p<0.001$. For the communicative learning, the data obtained was statistically significantly different for the different tests obtained, $F(1, 78) = 8.517$, $p<0.001$.

In addition, the Tukey Post Hoc Tests presented below show multiple comparisons between the pretest and posttest of the experimental and control groups regarding each type of learning.

Multiple Comparisons							
Tukey HSD							
Dependent Variable	(I) Pre_Post	(J) Pre_Post	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Emancipatory	Pre control	post control	.55417*	.190	.067	.059	1.049
	pre experimental	post experimental	-1.07083*	.190	.000	-1.566	-.575
	post control	post experimental	-1.18333*	.190	.000	-1.678	-.688
Instrumental	Pre control	post control	.54286*	.193	.059	.039	1.045
	pre experimental	post experimental	.57292*	.159	.000	.158	.987
	post control	post experimental	-1.25208*	.159	.000	-1.666	-.837
Communicative	Pre control	post control	.52143*	.193	.061	.0184	1.024
	pre experimental	post experimental	-.82500*	.193	.000	-1.328	-.322
	post control	post experimental	-1.36786*	.193	.000	-1.870	-.864

Table (4.5): The Tukey Post Hoc test that represents the significance of differences between pretest and posttest experimental and control groups.

It has been revealed that there was no significant difference ($p>0.001$) between the pretest control group and posttest control group. The significant difference found between the following groups: pretest experimental group and posttest experimental group; and posttest control group and posttest experimental group, within all types of learning. The differences between the means and the standard deviation of the pretest posttest control and experimental groups within each independent variable, emancipatory, instrumental, and communicative learning, were also represented (see Appendix H). The highest mean was shown to be 4.30 with the posttest experimental group and the lowest standard deviation 0.47 within the emancipatory learning. For instrumental learning, the highest mean is 4.24 and the lowest standard deviation is 0.47 with the posttest experimental group. In addition, the highest mean within the communicative learning is 4.39 with a low standard deviation of 0.44 that was found in the posttest experimental group.

The analysis of covariance ANCOVA was run and is presented below to compare several means adjusted for the effect of treatment on the students' posttest.

Levene's Test of Equality of Error Variances[a]			
Dependent Variable: Posttest			
F	df1	df2	Sig.
54.208	1	78	.000

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.[a]

a. Design: Intercept + Pretest + Groups

Table (4.6): The Levene's test of equality of error variances.

It is clear that the covariate significantly affects the dependent variable (students' posttest), because the significance value is less than 0.05. Therefore, the posttest results are influenced by the three types of learning. The Levene's test is significantly indicating that the group variances are not equal. The table below shows the significance between the groups.

Tests of Between-Subjects Effects						
Dependent Variable: Posttest						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	31.978[a]	2	15.989	18.403	.000	.323
Intercept	53.743	1	53.743	61.857	.000	.445
Pretest	.000	1	.000	.000	.989	.000
Groups	28.528	1	28.528	32.835	.000	.299
Error	66.899	77	.869			
Total	1186.690	80				
Corrected Total	98.877	79				

a. R Squared = .815 (Adjusted R Squared = .800)

Table (4.7): The analysis of covariate ANCOVA (tests of between subject's effects).

There are statistically significant differences ($p<0.05$) in posttest between the experimental and control groups when adjusted for pre-intervention pretest. The covariate (pretest) is not significantly affecting the dependent variable (posttest), because the significance value is more than 0.05. Therefore, the posttest is not influenced by the pretest. However, the effect of the treatment within groups is significant $p = 0.000$. The amount of variation accounted for by the treatment within groups has increased to 28.52 units and the unexplained variance has been reduced to 66.89 units. In order to validate the data, the

independent sample t-test was run to compare the differences of the posttest experimental and control groups. The results confirmed that there are significant differences between the posttest control group and the posttest experimental group. Another independent sample t-test was run to determine the differences between the pretest and posttest of the control group. The results show no significant difference between the two groups while there was significant difference shown between the pretest and posttest experimental groups (see Appendix H).

The table below shows a comparison between the posttest experimental and control groups. There are differences in responses of the posttest control group and posttest experimental group.

Independent Samples Test										
	Levene's Test for Equality of Variances			t-test for Equality of Means						
	F		Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Emancipatory	Equal variances assumed	53.041	.000	-5.367	78	.000	-1.183	.220	-1.622	-.744
	Equal variances not assumed			-5.367	48.893	.000	-1.183	.220	-1.626	-.740
Instrumental	Equal variances assumed	36.250	.000	-6.348	78	.000	-1.252	.197	-1.644	-.859
	Equal variances not assumed			-6.348	51.909	.000	-1.252	.197	-1.647	-.856
Communicative	Equal variances assumed	48.456	.000	-6.269	78	.000	-1.367	.218	-1.802	-.933
	Equal variances not assumed			-6.269	48.100	.000	-1.367	.218	-1.806	-.929

Table (4.8): comparison of independent sample t-test between posttest control group and posttest experimental group.

The results of the posttest experimental group in the emancipatory learning (4.30 ± 0.47) was found to be more than the posttest control group (3.12 ± 1.31), a statistically significant difference of -1.183 at 95% confidence interval, t (78) = -5.367, p = 0.00 (p<0.001). The results of the posttest experimental group in the instrumental learning (4.24 ± 0.47) was

found to be more than the posttest control group (3.02 ± 1.22), a statistically significant difference of 1.252 at 95% confidence interval, t (78) = -6.348, p = 0.00 (p<0.001). The results of the posttest experimental group in the communicative learning (4.39 ± 0.44) was found to be more than the posttest control group (3.02 ± 1.30), a statistically difference of 1.367 at 95% confidence interval, t (78) = -6.269, p = 0.00 (p<0.001).

4.1.3 Anticipated results of transforming students' learning

A multiple regression test was established in order to anticipate the transformation of students' learning due to being exposed to the treatment (emancipatory, instrumental, and communicative learning). The linear regression model $\gamma = \chi \beta + \varepsilon$ includes the polynomial regression model.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.903[a]	.815	.800	.71503	.815	55.812	3	38	.000	2.275

a. Predictors: (Constant), Communicative, Instrumental, Emancipatory

b. Dependent Variable: Students' Results

Table (4.9): The predicted r square of the emancipatory, instrumental, and communicative learning on students' results.

The data shows that the emancipatory, instrumental, and communicative learning could statistically significantly predict transforming students' learning, where F (3, 38) = 55.812, p<0.05 and the independent variables (emancipatory, instrumental, and communicative learning) accounted for 81.5% of affecting students' results. The regression equation was: predicted students' results = -12.478 – 0.125 x (emancipatory learning) + 0.474 x (instrumental learning) + 0.778 x (communicative learning).

The ANOVA table shown below confirms that the regression model result is statistically significant predictable of the dependent variable (Students' results) where p = 0.000, p<0.05.

ANOVA[a]

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	85.605	3	28.535	55.812	.000[b]
	Residual	19.428	38	.511		
	Total	105.033	41			

a. Dependent Variable: Students' Results

b. Predictors: (Constant), Emancipatory, Instrumental, Communicative

Table (4.10): The ANOVA analysis shows that the data is statistically significant.

A Pearson's product-moment correlation was run to assess the relationship between emancipatory, instrumental, communicative learning and students' results (see the table below).

Correlations					
		Students' Results	Emancipatory	Instrumental	Communicative
Pearson Correlation	Students' Results	1.000	.689	.669	.863
	Emancipatory	.689	1.000	.875	.627
	Instrumental	.669	.875	1.000	.517
	Communicative	.863	.627	.517	1.000
Sig. (1-tailed)	Students' Results	.	.000	.000	.000
	Emancipatory	.000	.	.000	.000
	Instrumental	.000	.000	.	.000
	Communicative	.000	.000	.000	.
N	Students' Results	40	40	40	40
	Emancipatory	40	40	40	40
	Instrumental	40	40	40	40
	Communicative	40	40	40	40

Table (4.11): The correlation between variables.

The analyses showed that there was a strong relation between variables where the strong correlation occurs between emancipatory learning and students' results, $r = 0.689$, $p < 0.05$, with a percentage of 47.4% of the variation on students' results. Another strong correlation occurred between instrumental learning and students' results, $r = 0.669$, $p < 0.05$, with a percentage of 44.7% of the variation on students' results. The last independent variable (communicative learning) was found to have a strong correlation with the students' results, $r = 0.863$, $p < 0.05$, with a percentage of 74.4% of the variation on students' results. It is important to note that a strong correlation was found between independent variables, where the strongest correlation was between instrumental learning and emancipatory learning, $r = 0.875$, $p < 0.05$. In addition, the correlation between communicative and emancipatory comes in the next rank at $r = 0.627$, $p<0.05$ and lastly is the correlation that was found between communicative learning and instrumental learning, $r = 0.517$.

4.1.4 The differences between males and females

An independent samples t-test was run to determine if there were differences in the responses of males and females in the posttest experimental group, as shown in the table below.

Independent Samples Test										
	Levene's Test for Equality of Variances			t-test for Equality of Means						
	F		Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Emancipatory	Equal variances assumed	.503	.482	1.180	38	.245	.175	.148	-.125	.475
	Equal variances not assumed			1.180	37.888	.245	.175	.148	-.125	.475
Instrumental	Equal variances assumed	.000	.984	-.604	38	.549	-.091	.151	-.398	.215
	Equal variances not assumed			-.604	37.525	.549	-.091	.151	-.398	.215
Communicative	Equal variances assumed	.202	.655	.348	38	.730	.050	.143	-.240	.340
	Equal variances not assumed			.348	37.915	.730	.050	.143	-.240	.340

Table (4.12): Comparison of independent sample t-test between males and females' posttest experimental group.

The results show that there are no significant differences between the males' and females' responses. The result from the females in the emancipatory learning (4.216 ± 0.45) was found to be slightly less than the males of the experimental group (4.39 ± 0.48), a statistical difference of 0.175 at 99.9% confidence interval, $t(38) = 1.180$, $p = 0.245$ ($p>0.001$) where there is no significant difference. The results from the females of the posttest experimental group in the instrumental learning (4.29 ± 0.45) was found to be slightly more than from the males' posttest experimental group (4.20 ± 0.506), a statistical difference of 0.0916 at 99.9% confidence interval, $t(38) = -0.614$, $p = 0.549$ ($p>0.001$) where there is no significant difference. The results of the females' posttest experimental group in the communicative learning (4.05 ± 0.78) was found to be slightly less than the males' posttest experimental group (4.42 ± 0.46), a statistically significant difference of 0.50 at 99.9% confidence interval, $t(38) = 0.348$, $p = 0.730$ ($p>0.001$) where there is no significant difference.

It is interesting to note that there were significant differences found between males and females in the posttest control group (see the table below).

Independent Samples Test											
	Levene's Test for Equality of Variances			t-test for Equality of Means							
		F		Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
										Lower	Upper
Emancipatory	Equal variances assumed	1.616		.211	-11.672	38	.000	-2.291	.196	-2.689	-1.894
	Equal variances not assumed				-11.672	33.806	.000	-2.291	.196	-2.690	-1.892
Instrumental	Equal variances assumed	2.822		.101	-8.984	38	.000	-1.991	.221	-2.440	-1.542
	Equal variances not assumed				-8.984	37.460	.000	-1.991	.221	-2.440	-1.542
Communicative	Equal variances assumed	.896		.350	-8.015	38	.000	-2.042	.254	-2.558	-1.526
	Equal variances not assumed				-8.015	37.893	.000	-2.042	.254	-2.558	-1.526

Table (4.13): comparison of independent sample t-test between males' and females' posttest control group.

The results of the females in the emancipatory learning (4.26 ± 0.49) was found to be more than the males of control group (1.97 ± 0.721), a statistically significant difference of 2.29 at 99.9% confidence interval, t (38) = -11.672, p = 0.000 (p<0.001). The results of the females of the posttest control group in the instrumental learning (4.016 ± 0.65) was found to be more than the males' posttest control group (2.02 ± 0.741), a statistically significant difference of 1.99 at 99.9% confidence interval, t (38) = -8.984, p = 0.000 (p<0.001). The results of the females' posttest control group in the communicative learning (4.05 ± 0.78) was found to be more than the males' posttest control group (2.01 ± 0.82), a statistically significant difference of 2.042 at 99.9% confidence interval, t (38) = -8.015, p = 0.000 (p<0.001).

4.1.5 Differences between the groups' mean

The data shows a significant difference between the pretest experimental and posttest experimental group; in addition, there are also significant differences between the posttest control and posttest experimental groups within the three types of learning. The following graph explains the differences between the mean scores of the experimental and control groups. The data shows that there is a significant difference between the control and experimental groups within the three types of learning.

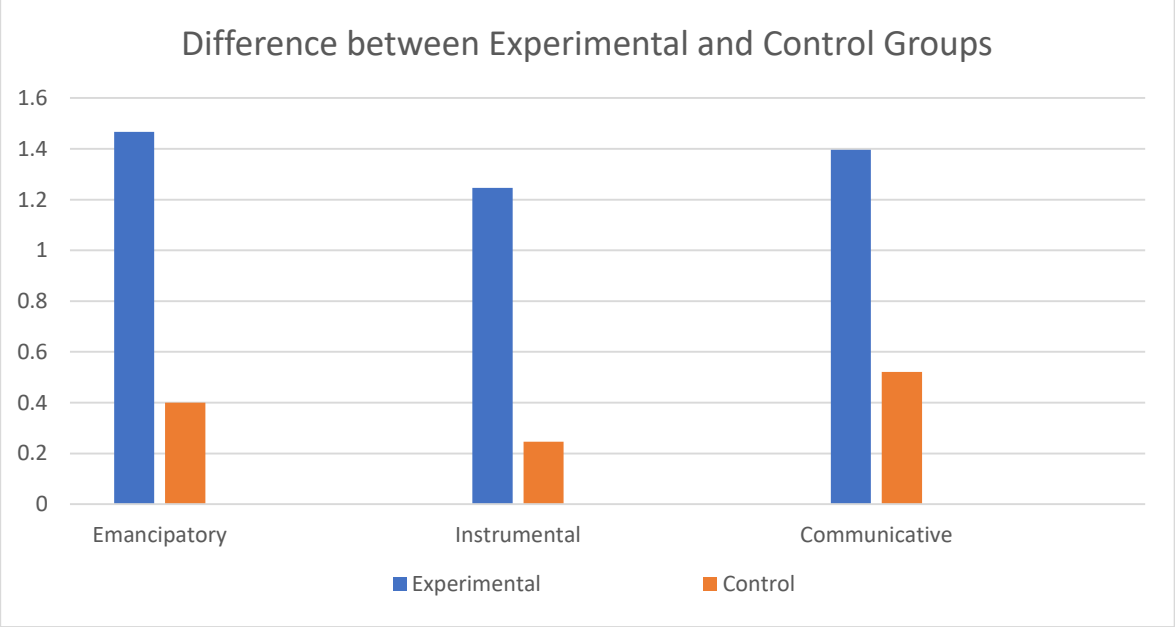

Figure (4.1): Difference between Mean scores of experimental and control groups.

The following graph shows a summary comparison between the pretest and posttest of the experimental and control groups within each types of learning. The data shows that there are significant differences between students' responses in the experimental group while there are slight differences between the students' responses in the control group.

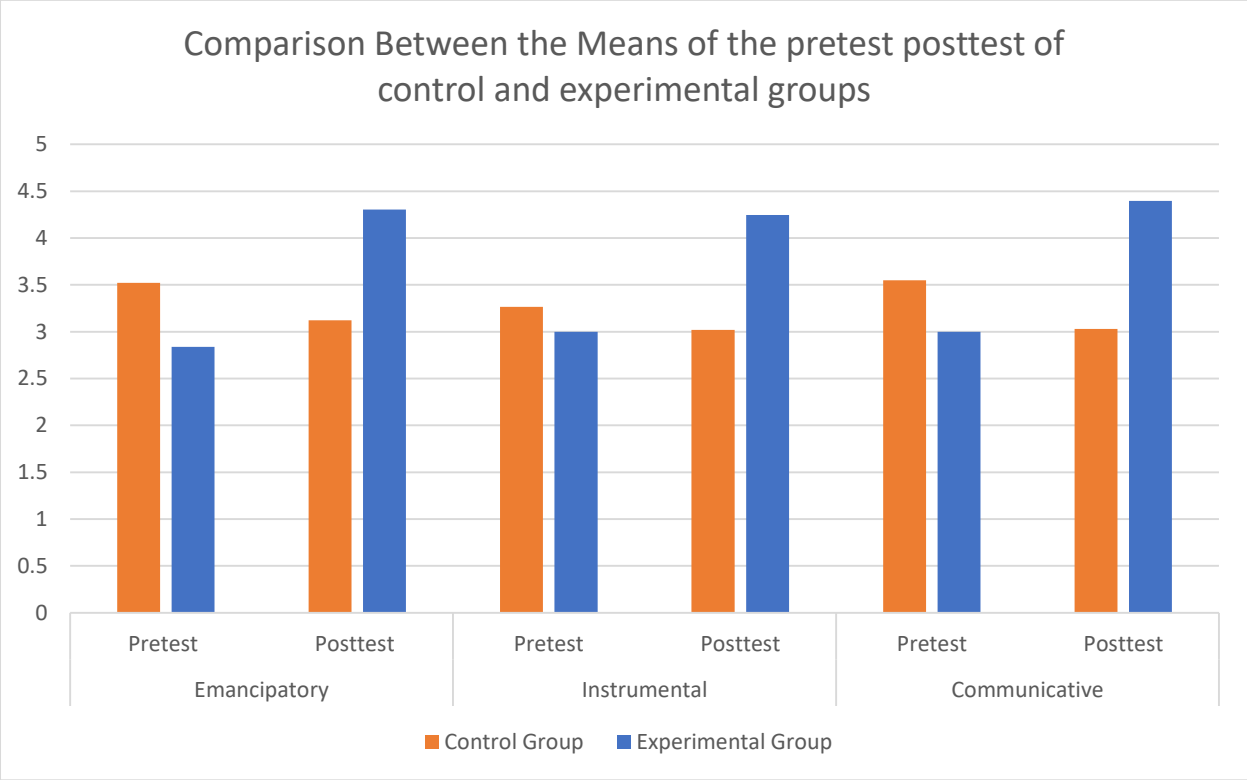

Figure (4.2): Differences between the pretest and posttest of the control and experimental groups within the three independent variables (emancipatory, instrumental, and communicative learning).

4.2 Variances of Students' Frames of Reference

The focus group discussion was done to address the fourth question of the study, which is: how does the students' frame of reference vary after being exposed to the transdisciplinary course and assessed authentically? A sample of the students was selected randomly from the experimental group. There were two discussion groups that formed a total of 12 students (6 males and 6 females). The focus group questions were open-ended questions and categorized according to the three types of learning: emancipatory, instrumental, and communicative learning. There were three questions in each category that represent the content, process and premise, based on Cranton's questions (1994). The researcher ran a discussion with the students who were encouraged to answer the questions while listening to and commenting on

their peers. The open-ended questions were asking students about their experiences of the graduation projects.

Emancipatory Learning

Regarding the emancipatory learning, the first question was focusing on content, the second question was about process, and the third question was about premise. Students were asked the following questions:

For the graduation project, what are your assumptions (point of view) regarding change?

Male and female students' responses were similar, where both felt the change and expressed it in their own opinions. For boys, students had different responses where some of them said that they had changed their opinions about topics that were not interesting to them before and after being exposed to them and were under pressure to solve complex problems in a short time. Some interesting discussions were interpreted as the following:

Student 1: "*It is to realize that what you think about before is different than what you have been convinced with after passing through the experience.*"

Student 2: "*The way of viewing things become different as I felt that I should think beyond the problems we face and consider the consequences of any answer.*"

Student 3: "I*t is also how you view yourself, how you see the problems and think about the answers that will take you through an experience and as a consequence will change how to approach the world.*"

For girls, they believed that the change is like "a caterpillar when it turns into a butterfly". In other words, it is not to improve ways of thinking but it is to change the habits and the mindsets about how to view the world. Other students shed light through a discussion as the following:

Student 1: "*It is to experience new environments that require friends' collaboration and support in order to complete tasks.*"

Student 2: "*The most interesting thing is that each member of the team knows her strengths and weaknesses that helped them to distribute tasks accordingly.*"

Student 3: "*It is an experience that you can reflect upon where I remember how I was thinking before and the way I think now have become totally different.*"

How did you obtain this change or know that your assumptions are valid?

Boys' and girls' responses for this question were all about the values they gained and made them change their points of view while others solidified their points of view after the experience they went through. Some students commented that testing their prototypes and evaluating themselves made them sometimes feel frustrated but they said that there is always

a route to be on the right track. This happens through their reflection, continuous discussions, and trials to improve their work. An interesting discussion from students included the following:

Student 1: "*I felt how important I did after presenting my work and being evaluated from experts in the same field which makes me insist of continuing on this path."*

Student 2: "*I discovered that I am acting perfectly in subjects that I didn't like before which makes me change my opinion about those subjects."*

Why should you revise/not revise your perspective?

All students (boys and girls) responded that they have to revise their assumptions. A few students clarified why they have to review their assumptions as the following:

Student 1: *"Because if I am right I will be more confident and know how to add more to my work and if I did something wrong so I need to change my work in order to improve it."*

Student 2: *"I like to have challenge and try to think how to overcome this challenge. It is like connecting puzzles to get the big picture".*

Instrumental Learning

For the instrumental learning, students were again asked three questions about content, process and premise. The questions are as the following:

What is the cause of change?

Students had interesting responses where boys and girls responded differently. The girls' responses were as the following:

Student 1: "*Adding the art tasks to our work makes me interested more in my project and thinking of it even after the school timing.*"

Student 2: "*I like thinking about my engineering project in a way that produces artistic product that benefits the community.*"

Some of the boys' responses were as the following:

Student 1: "*The challenging problem we had in our project was interesting, that forced me to change my perspective of viewing things and find another route*".

Student 2: "*I found the easiest way is to try and fail in mistakes till I found the best solution in solving my problem."*

Student 3: *"It was interesting to plan, design and create our own project where we were eager to create innovative ideas."*

Student 4: *"I feel responsible to think about an idea that will benefit my country and the world."*

How did you first realize the change?

The responses differ again between boys' and girls' discussions. The boys' responses were:

Student 1: *"I didn't realize the change but after I finished my project and got feedback from others, I started to get back to my journal and I realized the difference between my starting point and ending point".*

Student 2: "*I have changed my perspective several times especially in the stage of testing our prototypes where we had to think about other way to get it to work.*"

Girls realized change in an early stage while it was happening, as they were interested to experience art and design in an engineering concept. The following are some of their responses:

Student 1: "*We found that mechanical and electrical engineering are not only machines and boring, there are several interesting things that can be done.*"

Student 2: "*I put my time and effort into interesting tasks I am passionate about.*"

Then, other students remembered what had been their passions before accomplishing their graduation projects and how they have been changed.

Why is the change important to you?

Students feel the importance of change where all boys and girls had the same responses. Responses of students were as the following:

Student 1: "*I feel a strong sense of responsibility and feel proud serving my community.*"

Student 2: "*If I still stick to my ideas I will not give myself the opportunity to try new things which might be more beneficial*."

All students felt proud of their achievements and how they act as adults in their jobs. They ended the discussion that they still have more to do, and change will be the way that will take them to better ideas.

Communicative Learning

Regarding the communicative learning, it also involved three questions: the first was on content, second on process, and third was on premise. The questions asked were the following:

What do others say about this change?

Students' responses to this question were interesting, where all students (boys and girls) had the same responses. Students commented that they were happy when they discussed with their peers how they had changed their perspectives about viewing things and how this change benefits them. Some responses were interesting, as the following:

Student 1: "*I was learning from my peers' experience and how they changed their prototypes several times and every time, it was improving.*"

Student 2: "*I was getting more confidence in what I do when I listen to my peers and teacher that the change I did in my plans was beneficial to my work.*"

Student 3: "*Every time I share my thoughts with the teacher and my peers I get encouraged with what I hear about my work.*"

How has this change been socially influenced?

The question has been clarified for the students to be: how has the communication, collaboration, social life, etc. influenced this change? A discussion was run for this question where students were replying and commenting on each other. There was no difference between boys' and girls' responses. The following are some of the responses:

Student 1: "*Change has been influenced through the immediate actions taken after classroom discussions to improve our work.*"

Student 2: "*Communicating with experts has a great influence on our work as we feel that we are employees in a company and inventing new prototypes.*"

Why should you believe in this change?

Students responded that the change makes them feel that they are eager to learn and benefit their country. Interesting responses were as the following:

Student 1: "*I feel the value of the change after listening to my peers, teachers, and experts feedback about my work.*"

Student 2: "*I like setting my plans and put a target for myself to reach. This organizes my thoughts and make me convinced by changing my route in order to reach my target.*"

Student 3: "*Communicating with my peers who have similar interests and listening to experts shed light on the importance of change in benefiting my country and myself.*"

4.3 Summary of the Second Phase Results

The purpose of this phase is to find the cause and effect of the treatment (emancipatory, instrumental, and communicative learning) on transforming students' learning. A quasi experiment "pretest posttest control experimental group" was conducted and followed by focus group discussions. Before exposing students to the treatment, the equivalency and adequacy between control and experimental groups were measured through conducting one-way ANOVA and t-test. The results showed no significant difference between the pretest control group and the pretest experimental group. Then, the effects of the treatment (emancipatory, instrumental and communicative learning) on the experimental group was measured using one-way ANOVA, ANCOVA, and t-test. A significant difference was found between the pretest and posttest experimental group of students after being exposed to the treatment while there was no significant difference between the pretest and posttest control group of students who didn't receive the treatment. It is interesting and important to note that there is no significant difference between the males and females of the experimental groups while there is a difference found between the males and females in the posttest control groups. The multiple regression test is conducted in order to find the anticipation of transforming students' learning with regards to the three independent variables (emancipatory, instrumental and communicative learning). The results show that there is anticipation of transforming students' learning due to being exposed to the treatment. The correlation between the three independent variables are measured. Results shows a very strong correlation between emancipatory and instrumental learning (0.875). The correlation between the emancipatory and communicative learning was also strong (0.627), while the least correlation occurred between instrumental and communicative learning (0.517). In addition, the correlation between the students' results and communicative learning was shown to be the highest (0.863) followed by the correlation between students' results and emancipatory learning. The least correlation was between the students' results and the instrumental learning (0.669). However, all the correlations are considered to be high correlations as all of them were higher than 0.5. The focus group discussions were conducted with experimental groups only who shed light on the content, process and premise of the transformation that occurred on their learning. Students explained how the change occurred and how they recognized this change. Students are satisfied by their learning and became open minded to the different perspectives and points of view of others. The reflection and feedback helped them to transform their perspectives and develop new habits of mind. Students were independent learners who define, plan, and work towards their

goals and targets. They are engaged in insightful discussions with their peers and teachers as well as able to argue a point of view and contribute ideas during discussions.

4.4 Lesson Plans Analysis

Document analysis is used to address the first question of the study, which is: How is the authentic assessment planned in the transdisciplinary STEAM curriculum? It was found that the authentic assessment used was aligned to the desired outcomes (transdisciplinary curriculum) and the instructional activities given to students. The lesson plans collected for data analysis were selected from three courses and a graduation project of the engineering science cluster. The first course is the AutoCAD software that is essential for students to learn in this cluster. This course is a prerequisite for most engineering courses and is required for the completion of the graduation project. This course integrates the technology, engineering and mathematics with less focus on science concepts. It is a college-level course that is taught in a vocational institute for grade 12 students. The second course is electrical principles and application that is considered to include integrated concepts of science (physics), technology and mathematics in the form of the engineering concepts. This course is taught to grades 11 and 12. The third course is the robotics course that integrates the science, technology, engineering and art with less focus on mathematics. The graduation projects are fully planned and designed by students with teachers' guidance. The template of the lesson plans used for the courses differ from the ones used for the graduation project. The lesson plans of the courses involve the three categories of the backward design. The first category is the desired outcomes that include the objectives, big idea, contents, competencies, and essential questions. The second category is the assessment that includes assessment as learning, named "non-stop assessment". Then, the learning plan that describes the sequence of the lesson. Finally, the lesson plan ends by reflection of teachers' work where it involves questions that guide teachers through reflecting on their work (see appendix H). The lesson plan template is designed to focus on certain areas of students' learning. There is a focus on writing opportunities where teachers have to clarify how students further extend their thoughts through writing, which is considered an effective way to be engaged in emancipatory learning and influence their English Language Art. In addition, reflection has an important focus where there is more than one area of reflection in the learning process. The reflection is identified in the lesson plans to be at the beginning of the lesson, during the learning process, through the use of assessment, and at the end of the lesson. Another important focus is on STEAM / 21st century skills where teachers

have to identify how they will incorporate the 21st century skills and STEAM into their lessons which indicates the engagement of students in reflective, communicative and instrumental learning. It is important to note also the focus on the communicative and cooperative learning where the teachers have to identify how the students are going to collaborate, cooperate and communicate during the learning process (see Appendix H).

The lesson plan template used for the graduation projects is also categorized into three categories but with less detail than the template used for the courses. The lesson plan starts by basic information of the class, date, time, number of periods, and teacher name. Then, it is categorized into learning outcomes, main part of the lesson that includes the instructional activities and the methods used for the assessments. At the end of the lesson plan, there are two boxes: the first one is for reflection and comment of teachers about the lesson; and the second box is what is expected from students for their next lesson (see Appendix H). A comparison between the lesson plans is interpreted through three categories: Know (knowledge), Do (skills), and Be (competencies) based on Drake's model (2010). For the first category "Know", the important content for students to know has been identified. Regarding the "Do" category of the lesson plan analysis, it identifies the three levels of skills: lower-order skills, discipline specific skills, and interdisciplinary skills. The lower-order skills require students to regurgitate existing knowledge through using the following verbs: list, recall, identify, describe, summarize, recognize, explain, and illustrate. The discipline specific skills require students to construct and interpret, plan their work, design, compare, contrast, perform, and create. The interdisciplinary skills are the higher-order thinking skills where complex performances are applied. Regarding the "Be" category, it shows the outcomes of changes, habits and values students acquire, such as respect, teamwork, and citizenship. The lesson plan analysis is divided into two categories: courses and graduation project. The analysis of the courses (AutoCAD, Electrical Principles, and Robotics) are categorized in the table below according to the Know, Do and Be (KDB) model of Drake (2010). This is followed by analysis of the graduation projects using the same categories.

4.4.1 First Category: "Know"

Regarding the level of knowledge in the courses, the themes identified for all lesson plans of the courses and graduation projects are age-appropriate and relevant to students. The level of knowledge identified clearly the important content and knowledge students should know. The lessons of the electrical principles and application course show meaningful contexts

for students to learn, where their interests and motivation are encouraged as well as the extension of what they have learned into new situations through the communicative learning. Some worksheets and Socrative applications were used and rich feedback provided to students. The important content for students to know has been identified. In all lesson plans of the courses and graduation projects, the level of knowledge is identified where the focus is on the concepts, enduring understanding, and principles and theories, which are considered to be at a higher level of knowledge. However, the facts and topics that are considered to be the lowest level were not mentioned in the graduation project lesson plans. Furthermore, two of the lesson plans of a course failed to identify the enduring understanding or the big idea of the lesson. However, there was connection between what they are doing to real life. These have been shown in the AutoCAD course where the lessons focused on drawing 2D and 3D modelling using technology and mathematics contents. The degree of integration was designed to be the strongest integration which is known as the third way of Dugger and Fellow's (2011) framework. It lies in integrating all subjects (science, technology, art, and mathematics) within the engineering course. However, it was clear that the integration between subjects is stronger in the graduation projects. Regarding the assessment design in the courses, they were authentic tasks in the shape of projects, real-life problems, performance tasks, etc. For the graduation project, the formative assessments used are reflecting the KDB bridge where there is alignment between the assessments and the desired outcomes. Both of them provide ways to celebrate learning where some students reflect on their work and present achievements to their peers, in addition to the bonus given to them in innovating and extending their learning. Handouts of instructions and rubrics were handed to students in order for them to know what is expected from them. The pace of assessments is broadly even where it allows students to rest and plan ahead. The lesson plans of the courses did not mention if the assessment requires an external audience to assess the students' performance. However, in graduation projects, the kinds of assessments used do require an external audience to assess the students' performance. Regarding the guided questions used in the courses and projects, they provide a framework for the lesson, guide students' learning, encourage inquiry and multiple answers, and encompass a substantial part of the lesson. The graduation projects' guided questions give students opportunities to alternate between the divergent and convergent thinking.

A few lessons were not built on students' interests while the projects were mainly designed based on students' interests. However, the main points for the next lesson are discussed with students and ideas for homework are offered to them, which they can choose from. Teachers wrote students' feedback on the lesson plans for further improvement of the

lesson. Some lessons mentioned the extension of students' learning to future work, which was given at the end of the lessons. All the projects are based on students interests and follow the same goals. The flipped classrooms are used in designing and planning the activities and explaining important topics that can be used in solving students' problems. In the main part of the lesson where the activities are introduced, students are instructed to work actively in groups to complete their tasks. For example, students should work together to have at least four ideas and will take approval from the instructor. They discussed the connection of the mechanical and electrical parts to their work and its value in their lives. They organize their work while solving complex problems and interconnect between the divergent and convergent thinking in order to get the right route to follow. They used their previous learning and transfer it into new situations. They used their own journals where they go through the meaning of hypothesis and the reasoning behind including this in their projects. They recorded the collection of data and its analysis through using their mathematical and analytical skills.

4.4.2 Second Category "Do"

All the levels of skills are identified in the objectives of the lesson plans. However, the focus is on the highest of skills level which include the interdisciplinary skills that require complex performance and use of the information through mastering the following skills: information management, inquiry, critical thinking, communication, and problem-solving. The other high level of skills identified in the lesson plans of the graduation projects is the discipline specific skills which require students to be actively engaged in the learning processes where they construct and interpret, design, compare, perform, and create. The performance based assessments in all lesson plans include meaningful and relevant indicators of quality performances. The kind of assessments used allow students to integrate between the knowledge and the skills, such as: self-assessment, peer assessment, performance tasks, rubrics, journals, portfolios, observations, and checklists. In emancipatory learning, the students' self-assessment, peer assessment, rubrics, and observation are used in all lesson plans. In addition to these assessments, the robotics lessons also used performance tasks and journals as essential assessments. The opportunity for students' writing tasks was shown in the robotics course and lacked in the other courses. On the other hand, opportunities for students' writing is mentioned clearly in the lesson where they have to record steps and reflect using their iPad and/or journal. The process of the projects was discussed with the students and raising awareness about the stages of the projects took place. In instrumental learning, the type of activities in all lesson

plans engage students in instrumental learning through inquiry and problem-solving tasks. There are enough variety and choices of activities to address diverse learning needs. Most of activities on the courses are connected to the guiding questions and aligned to the objectives; however, a few of them were aligned only to the objectives as the guiding questions were missed. The activities are aligned to the culminating assessment and KDB model. However, the activities used in graduation projects are connected to the objective and the learning outcomes of the projects, the culminating assessments, and the KDB model. In graduation projects, students are more responsible where they are leading the learning process; identifying the problem; suggesting ideas; discussing the freehand drawings, researching, completing AutoCAD drawings; formulating surveys; and presenting their plans. In communicative learning, all lesson plans require students to work individually and in a communicative learning environment. Students have to work with their peers in order to complete authentic tasks that require communication and collaboration. In addition, it was planned that they have to teach each other and clarify concepts when needed within their groups. The activities are connected to the objective and the learning outcomes of the projects, the culminating assessments, and the KDB model. The use of authentic assessment is an essential part of learning process. The questions in students' collaborative work were predicted by teachers and planning was provided accordingly. The latest mechanical machines were provided to students, with special trainers and experts. Students have the opportunity to experience different careers through their projects and help in the completion of their work. Dialogues between students to students and students to teachers were mentioned in the plans of the graduation projects in order to give opportunity to feedback, reflect critically, and change their perspectives.

4.4.3 Third Category "BE"

Teachers mentioned that by end of each lesson students acquire some habits and values such as respect, teamwork, and citizenship. Teachers plan the lessons for students to demonstrate self-direction, reflection, cooperation, self-evaluation, making good choices, and being open to others. Each lesson plan includes time for students' post-conference where they discuss feedback and set plans to improve their work. The laboratory tasks mentioned in the lesson plans were full of independence learning where students are engaged in communicative and reflective learning. The robotics course has the highest number of authentic assessment tasks used and the highest integration between subjects. In graduation projects, some values and habits were identified in the lesson plans where the aim is to develop the teamwork, learning

and innovation, personal and social, and national and global citizenship skills. The students demonstrate the self-direction in their learning process, reflection on their work, setting their own goals; cooperate together; self-evaluate their work; and making good choices. All the lesson plans involve time for students' post-conference where they receive feedback and set plans to improve their work, in addition to the regular feedback students receive from their peers and from their teachers. Extension to future learning is considered in the lesson plans. The group discussions and experimental learning takes place in the learning process where they learn from their mistakes (failure-driven approach).

4.4 Curriculum Team Questionnaire Results

The curriculum team questionnaire is used to address the second question of the study, which is: What are the curriculum developers' and teachers' perceptions and practices in designing and planning the transdisciplinary STEAM curriculum?

The participants who are involved in this study are the curriculum developers and teachers who started the questionnaire at the first section which is demographic information about the participants. The second section is closed-ended items that are used to investigate the curriculum developers' and teachers' perceptions and their practices in designing and planning a transdisciplinary STEAM curriculum using authentic assessments. The third section is closed-ended items that ask them about their perceptions of developing students' skills through the use of three types of learning: emancipatory, instrumental, and communicative. The last section is open-ended questions where the participants explain their perceptions in the areas that cannot be investigated by closed-ended items. The analysis of the questionnaire is as the following: characteristics of curriculum developers and teachers; perceptions and practices of curriculum developers and teachers (curriculum and assessment design, emancipatory learning, instrumental learning, and communicative learning); and participants' deep meanings of perceptions.

4.4.1 Characteristics of the Curriculum Developers and Teachers

The first section of the questionnaire is the demographic information that was asking participants about their highest level of education per specialization. The data shows that the highest percentage of the participants who have bachelor and doctorate degrees were in the engineering team, while the highest who have master's degrees were from the science team. The total number of the participants who have a bachelor degree is 43.86%, master's degree

38.60%, professional degree 12.28%, and doctorate degree 7.02%. The graph below shows the differences between participants' level of education in each specialization.

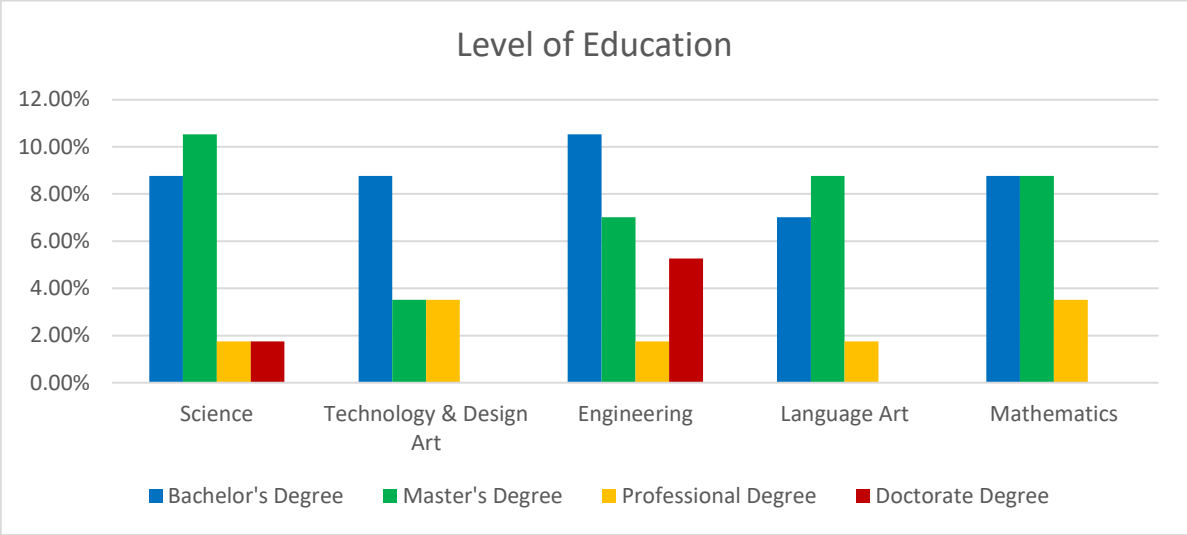

Figure (4.3): The level of education for participants who are involved in the curriculum team.

Regarding the gender differences, the data shows that the males in the science and engineering team were equal in percentage where they are the majority of participants who form 21.06% of the total while the majority of females were in the engineering and mathematics teams. The highest percentage of the females from the engineering team was 14.04% and the females from the maths team was 17.54%. The female and male participants were equal in the science team to form 10.53% each. Similarly, the females and males in the language art team were equal, to form 8.77% each. The total number of females (59.65%) was higher than males (40.53%). However, the similarity was in the female and male participants from the science team, who are equal and who form 10.53% each.

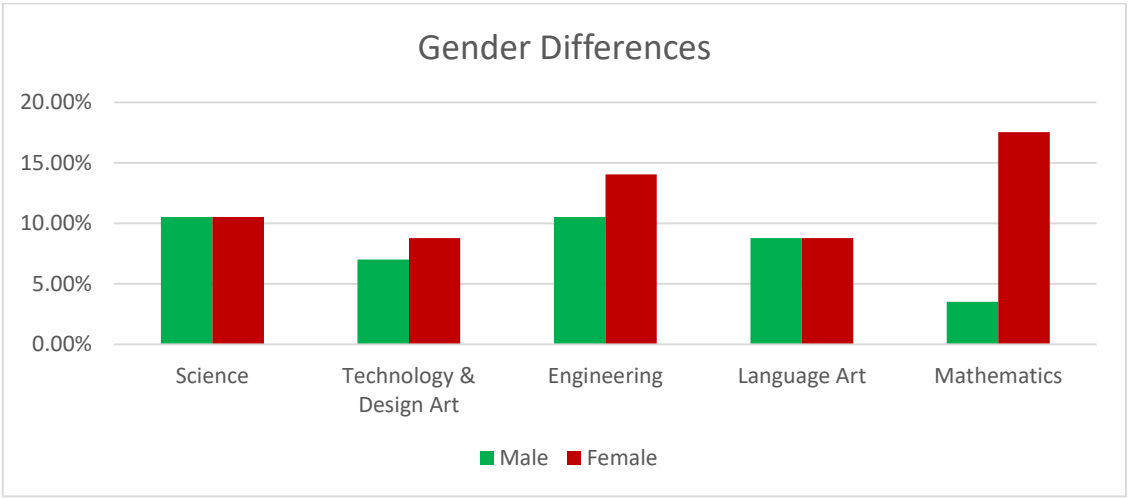

Figure (4.4): The gender differences between participants.

The data shows that the years of experience differ from one category to another with different percentages that are similar to each other. However, the majority were the participants who have 11 to 15 years of experience and precisely were in science (12.28%) and engineering (14.04%). This category forms 48.36% of the total number of participants while the second category were the participants who have 6 to 10 years of experiences to form 24.56% of the total amount. The other two categories (0 to 5) & (16 to 20) years of experience have the same percentage to form 15.79% each.

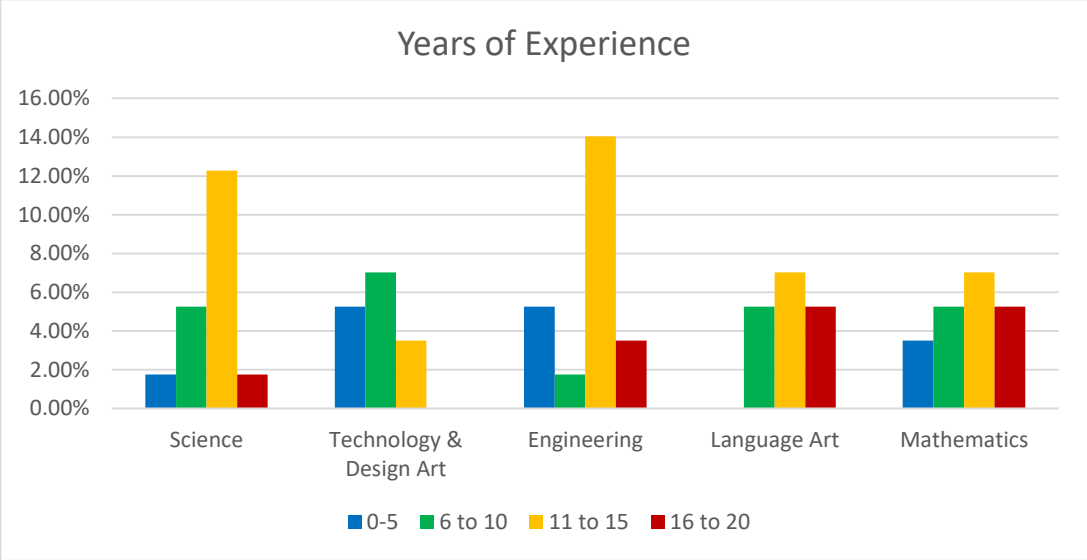

Figure (4.5): The years of experience of participants per specialization.

The last question of the demographic information is about the positions of the curriculum team per specializations. The data shows that the highest percentage of the participants was in the engineering specialization where 7.02% of the participants are curriculum developers with different majors of mechanical and electrical engineering. The science, language art, and mathematics have the same percentage of curriculum developers while no participants in technology and design art were acting as curriculum developers. The participants who were acting as coordinators were found in technology & art design, engineering and mathematics, with low percentages. Similarly, the lead teachers were found in science, engineering, language art, and mathematics with low percentages in each. The majority of participants were acting as teachers in all specializations where the highest percentages were found in the science (14.04%) and engineering (12.28%). The percentage of teachers was 56.14% from the total number of participants. All the participants were divided into two groups in this study to present a curriculum developer group (developers & coordinators) and teacher group (lead teacher and teacher). This is because developers and

coordinators were not involved in teaching and both are involved in designing and planning the curriculum while lead teachers and teachers are involved in teaching.

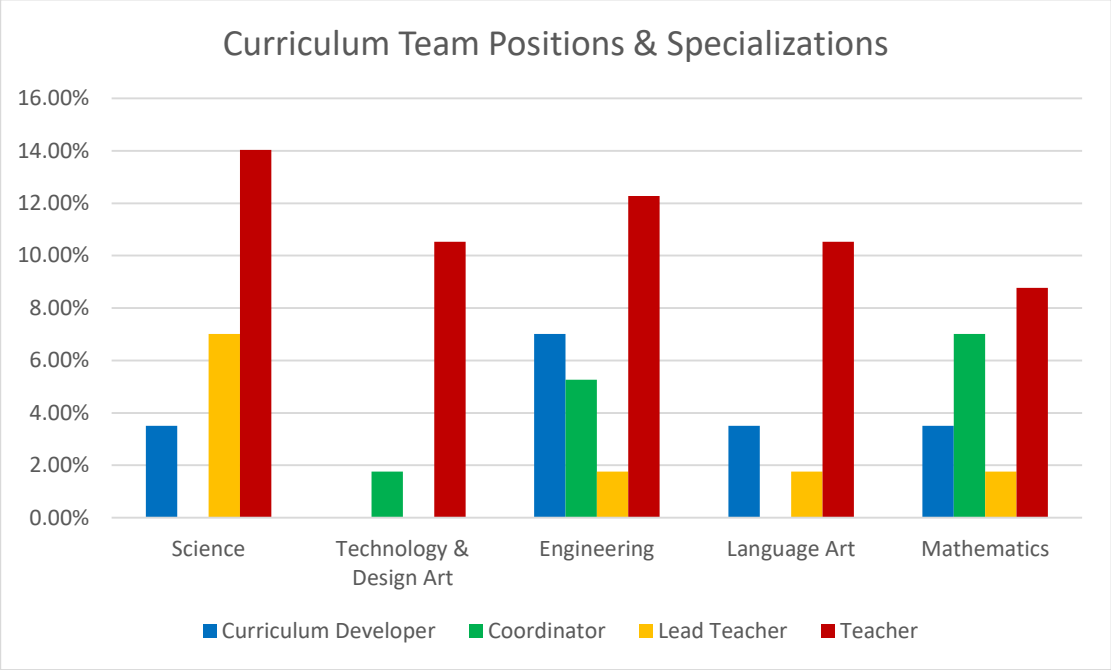

Figure (4.6): The curriculum team positions and specializations.

4.4.2 Perceptions and Practices of Curriculum Developers and Teachers

The results of the second section of the questionnaire were interpreted based on the framework of the study to form the following categories: curriculum and assessment design, emancipatory learning, instrumental learning, and communicative learning. The results involved the responses of curriculum developers and teachers as a whole group in addition to teachers' responses per specializations in order to show the differences between responses per specializations. The responses of the design of transdisciplinary curriculum and authentic assessment are represented first, then emancipatory learning that includes critical thinking and independent learning skills. Then, the instrumental learning that includes creativity and innovation and problem-solving skills are presented next. Finally, communicative learning that includes communication, collaboration, and self-direction skills are presented.

Curriculum and Assessment Design

The first part in this section discusses the participants' responses regarding designing the transdisciplinary curriculum using authentic assessment. The number of participants who responded to this questionnaire were 21 curriculum developers and 30 teachers from all specializations.

The results show that 100% of responses are between strongly agree and agree in five items in the category of curriculum and assessment design. This highest item has the highest

mean (4.66) with 0.57 standard deviation where the design of the transdisciplinary curriculum relates closely to career goals and practices. The other highest item is that the design of the transdisciplinary curriculum using authentic assessment affords students' engagement and active learning, where the highest mean is 4.61 and standard deviation is 0.49 (see Appendix J).

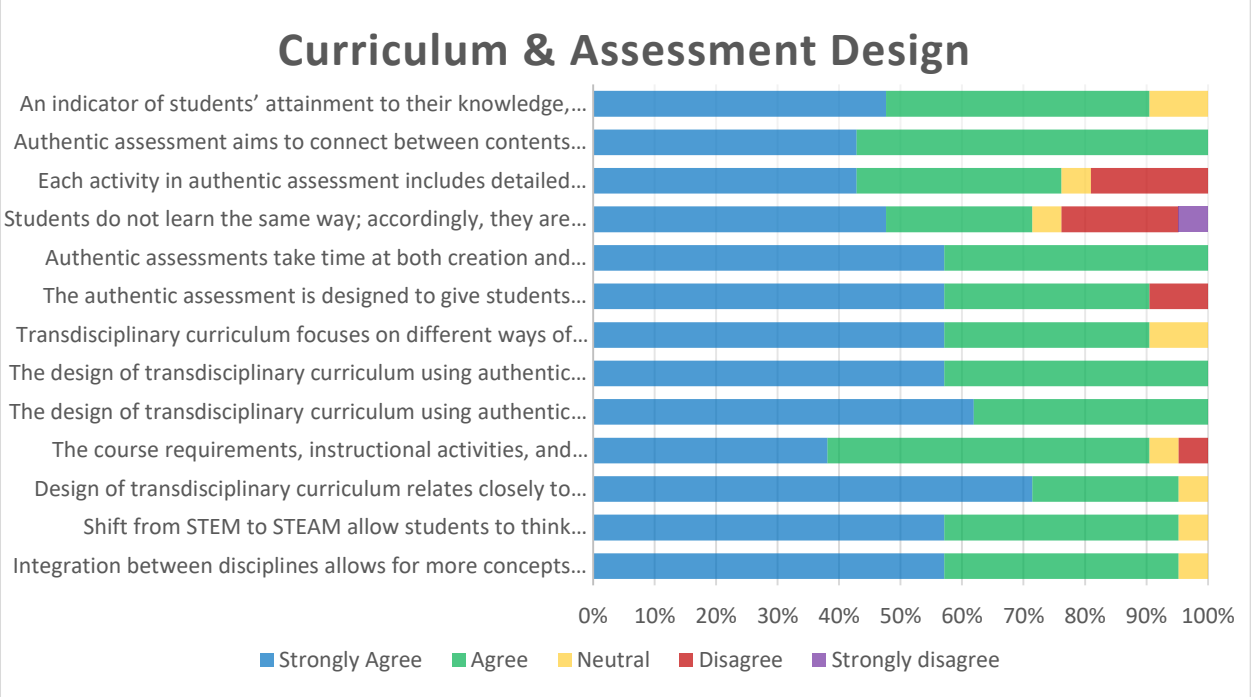

Figure (4.7): The curriculum developers' responses about curriculum and assessment design.

The highest mean in the teacher responses about the designing of transdisciplinary curriculum using authentic assessment was 4.33 with 0.66 standard deviation. This has been shown in one item of this category where 90% of participants' responses were between strongly agree and agree about shifting from STEM to STEAM allows students to think divergently where each create a different product based on their points of view.

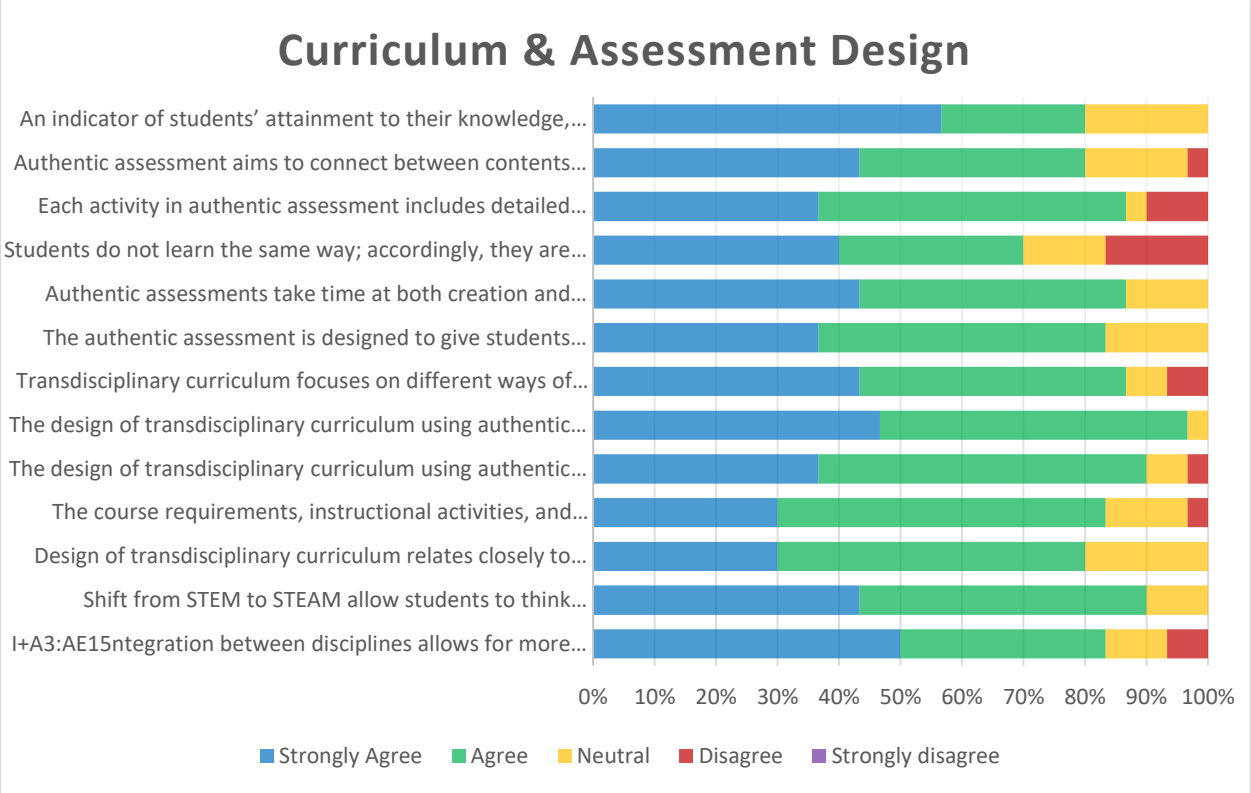

Figure (4.8): The responses of teachers in all specializations on designing transdisciplinary curriculum using authentic assessments.

The following graph is showing the differences of responses between the science, technology, engineering, language art and mathematics teachers. It has been shown that the percentage of teachers' agreement ranks from high to low as the following: engineering (91.76%), science (90.39%), technology (89.75%), language art (87.69%), and then mathematics teachers (80.13%).

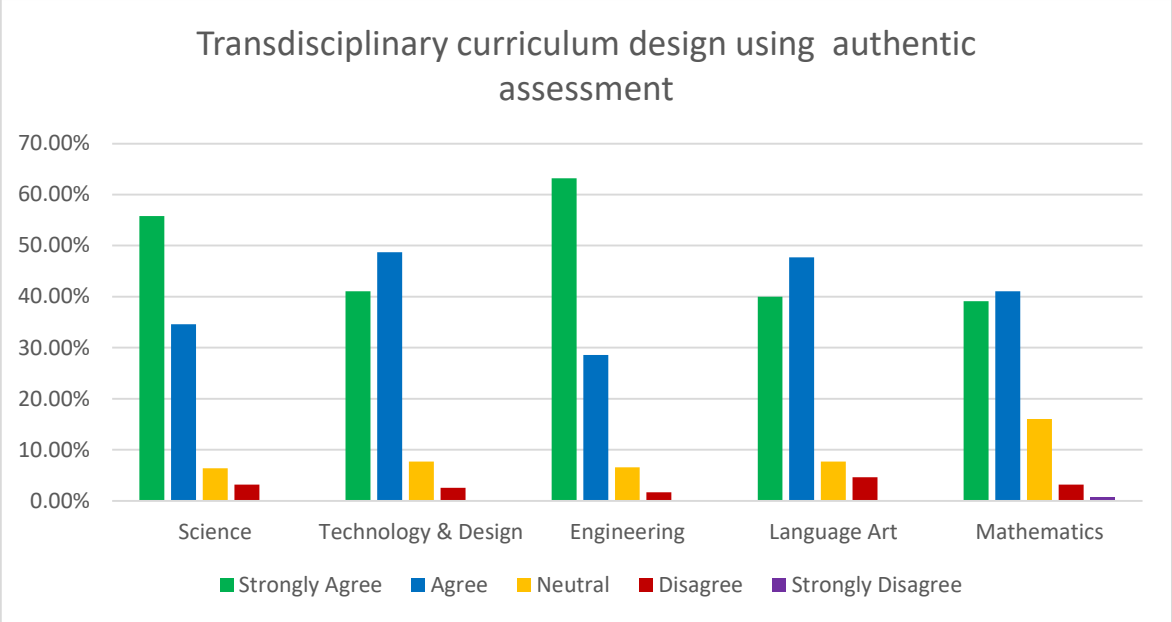

Figure (4.9): The differences between teachers' responses in transdisciplinary curriculum design using authentic assessment per specializations.

The responses from curriculum developers and teachers differ regarding curriculum and assessment design. Curriculum developers reported that giving instructions and guidelines for students is important in order to ensure the completion of the requirements. In addition, students' engagement and active learning is high through the design of transdisciplinary STEAM curriculum using authentic assessment. Furthermore, they mentioned that integration between disciplines allows for more concepts to be taught in less time and at higher levels. On the other side, teachers pointed out that shifting from STEM to STEAM allows students to think divergently where each creates a different product based on their points of view. In addition, they mentioned that authentic assessment tasks take time at both creation and grading stages.

Emancipatory Learning

The highest mean of this category is 4.45 with a low standard deviation of 0.51 where 100% of responses are between strongly agree and agree that students can gather, evaluate, synthesize information from different sources.

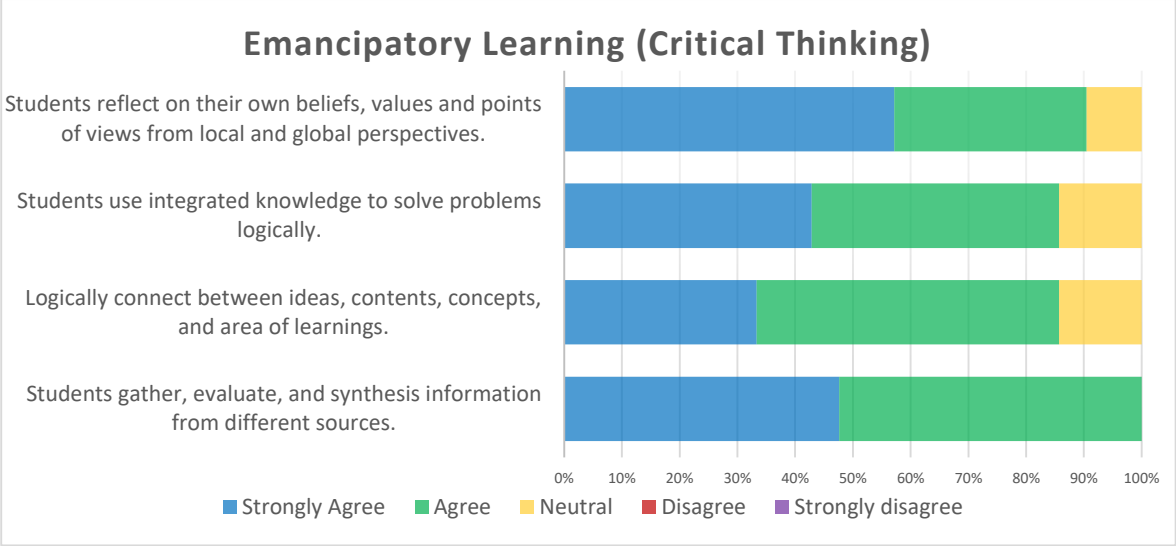

Figure (4.10): The curriculum developer responses of critical thinking skills in emancipatory learning.

The highest mean of teachers' responses in the critical thinking of emancipatory learning was 4.50 and standard deviation 0.57 in two items. The responses of teachers were about 97% of all teachers who were between strongly agree and agree that students gather, evaluate, and synthesize information from different sources; in addition they reflect on their own beliefs, values and points of views from local and global perspectives.

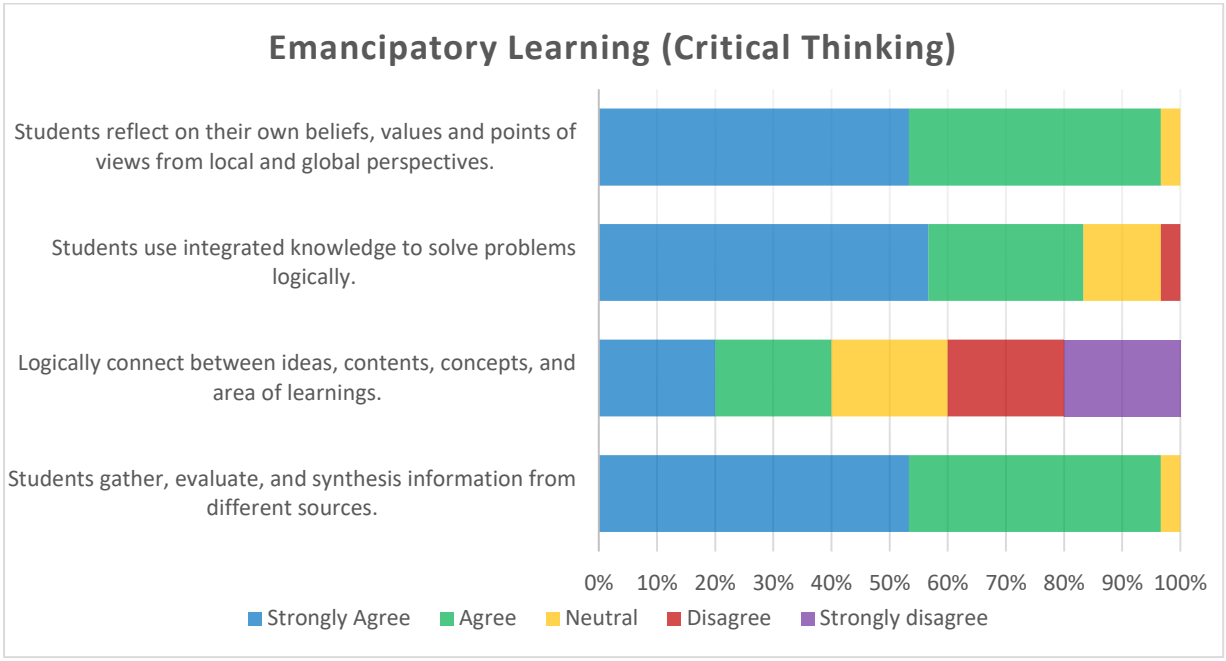

Figure (4.11): The responses of teachers in critical thinking skills of emancipatory learning.

The ranks of teachers' responses in the critical thinking of emancipatory learning is in the following sequence: language art (95%), engineering (92.85%), science (91.67%), then mathematics (85.41%).

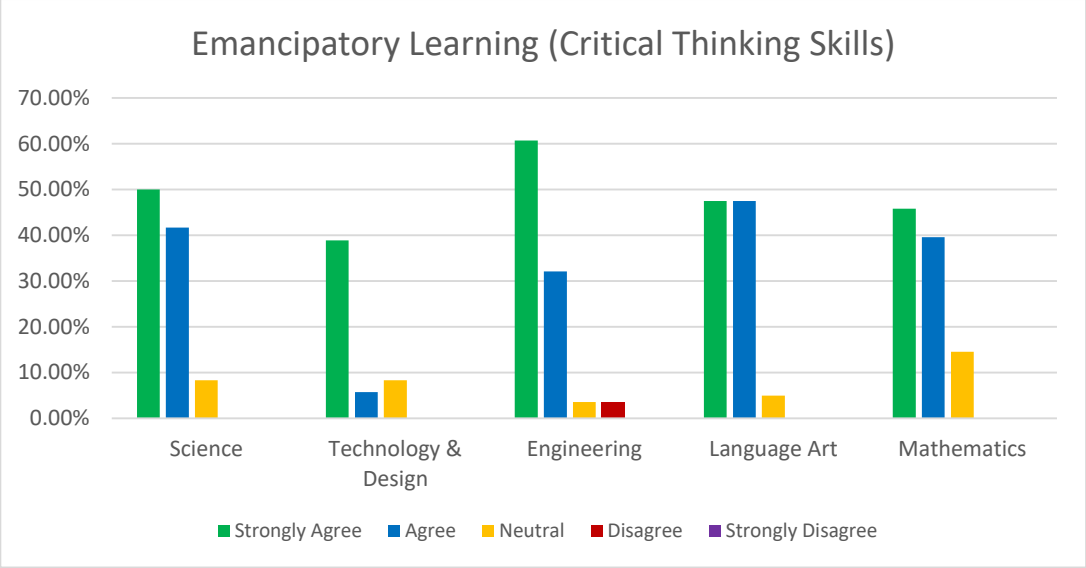

Figure (4.12): The differences between teachers' responses in emancipatory learning (critical thinking skills) per specializations.

The highest standard deviation of the independent learning skill of emancipatory learning is 4.57 with a standard deviation of 0.60 where 95.23% of responses were between strongly agree and agree that students use an extensive range of resources and technologies independently.

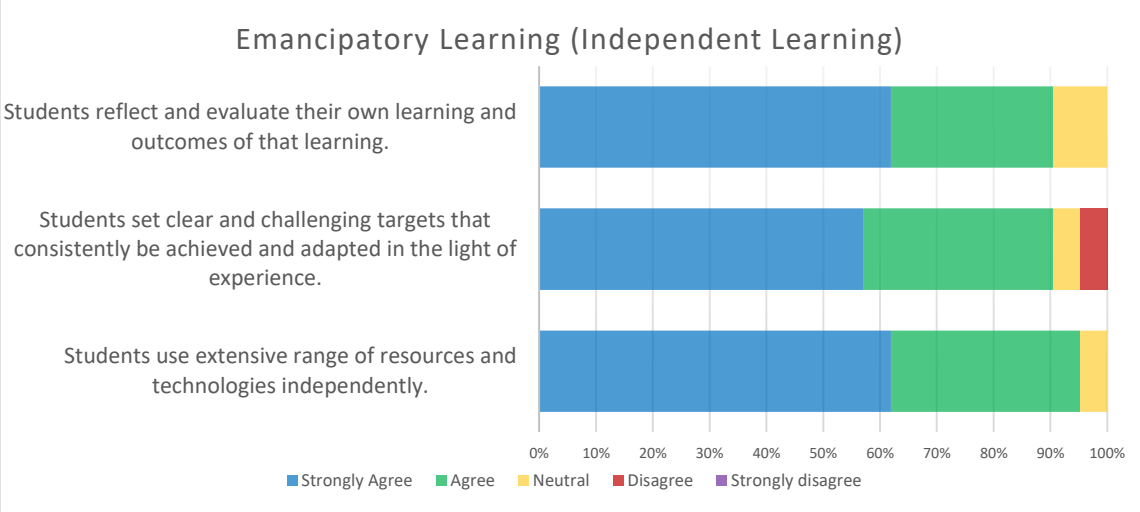

Figure (4.13): The curriculum developer responses of independent learning skills in emancipatory learning.

The highest mean of the teachers' responses in the independent learning skills of emancipatory learning is 4.43 with 0.67 standard deviation where 90% of teachers were between strongly agree and agree that students use an extensive range of resources and technologies independently.

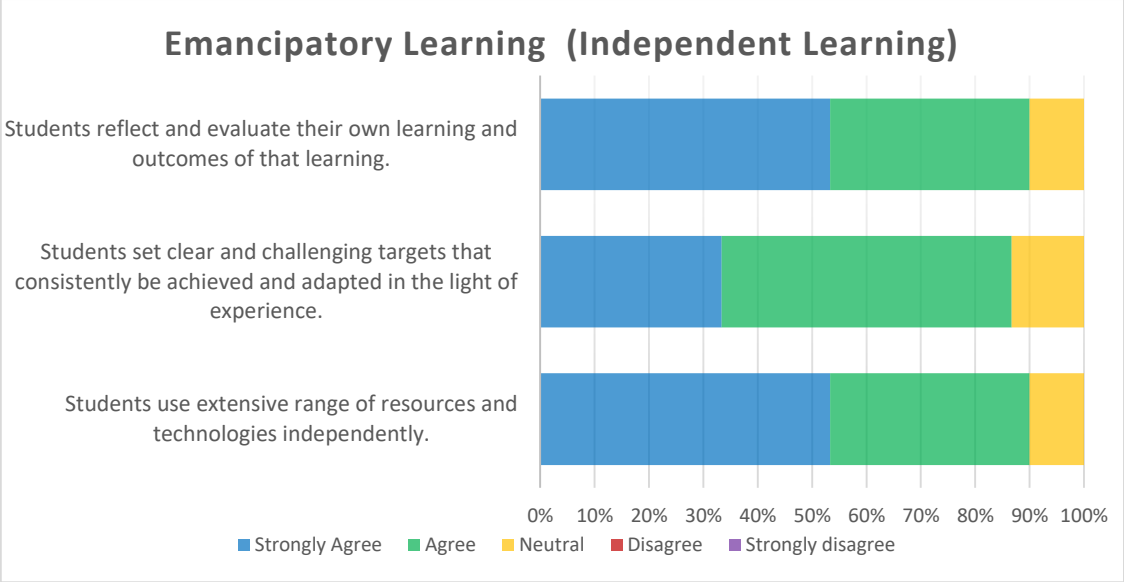

Figure (4.14): The responses of teachers in independent learning skills of emancipatory learning.

The highest percentage of agreement of teachers' responses was with the engineering teachers (97.62%) followed by technology and design (92.59%), language art (90%), science (88.89%), then mathematics (83.42%).

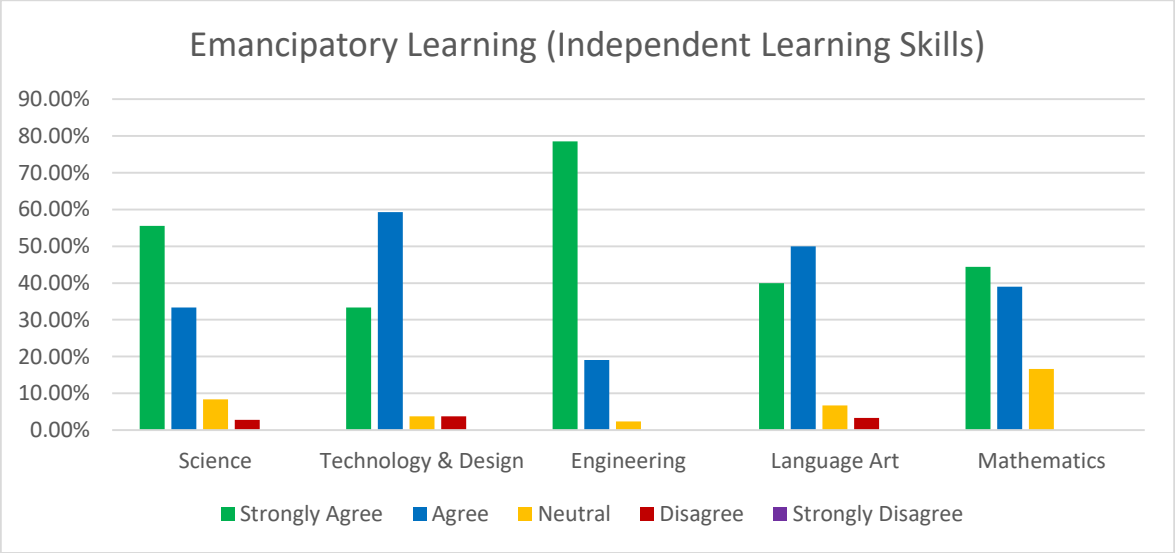

Figure (4.15): The differences between teachers' responses in emancipatory learning (independent learning skills) per specializations.

For the critical thinking skills, the curriculum developers and teachers reported that students reflect on their own beliefs, values, and points of view from local and global perspectives. Curriculum developers added that the design of transdisciplinary curriculum using authentic assessment allows for logical connection between ideas, contents, concepts,

and areas of learning. On the other side, teachers stated that students gather, evaluate and synthesize information from different sources.

For the independent learning skills, curriculum developers reported that students can set clear and challenging targets that can consistently be achieved and adapted in the light of experience. In addition, both curriculum developers and teachers mentioned that students can reflect and evaluate their own learning and outcomes of that learning. Furthermore, they pointed out that students use extensive range of resources and technologies independently.

Instrumental Learning

The highest mean of creativity and innovation skills of instrumental learning is 4.57 with a standard deviation of 0.50 where 100% of responses were between strongly agree and agree that students can generate innovative ideas and ways of thinking in solving problems.

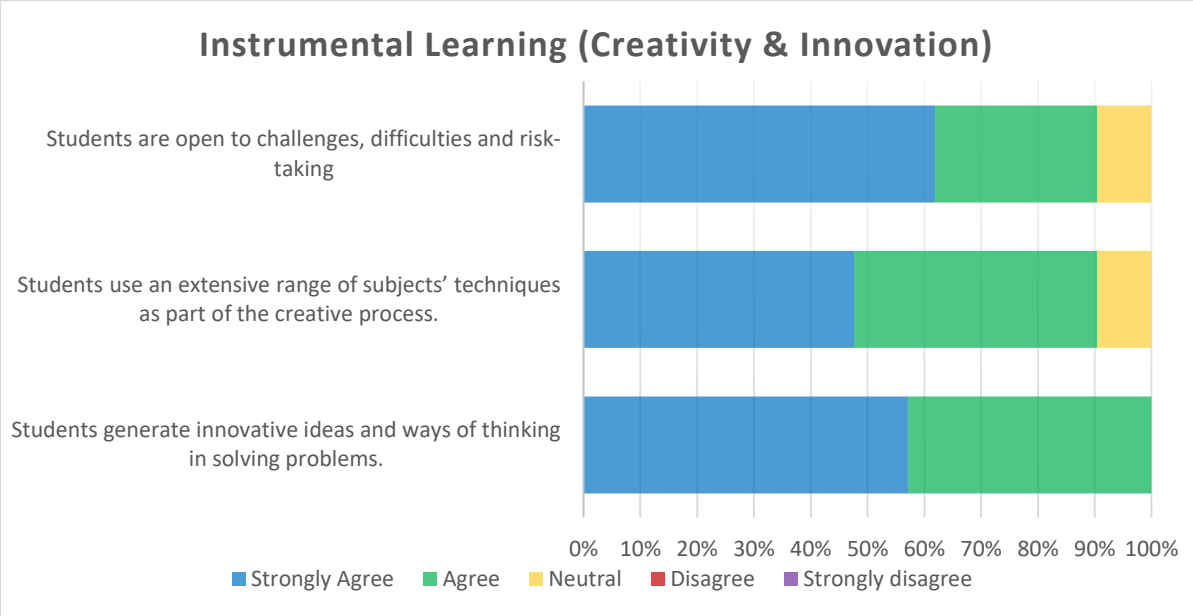

Figure (4.16): The curriculum developer responses of creativity and innovation skills in instrumental learning.

The highest mean of teachers' responses in the creativity and innovation skills was 4.33 with 0.66 standard deviation where 90% of teachers were between strongly agree and agree that students generate innovative ideas and ways of thinking in solving problems.

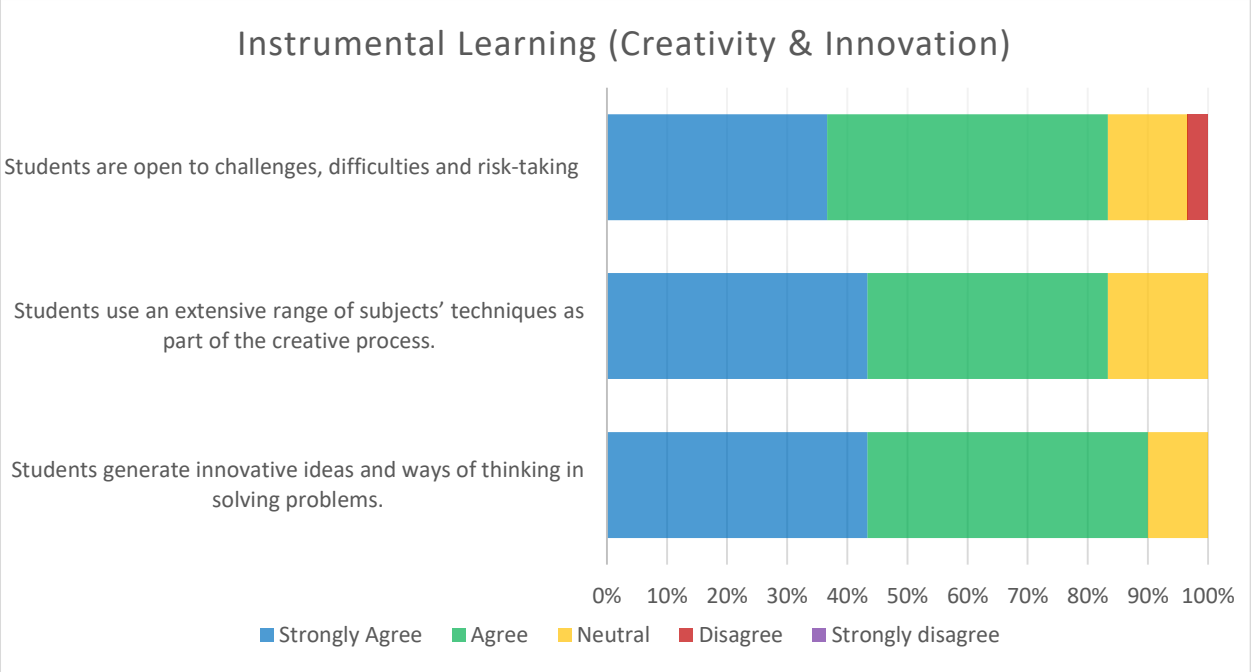

Figure (4.17): The responses of teachers in creativity & innovation skills of instrumental learning.

The highest percentage of agreement of responses about creativity and innovation skills in instrumental learning was with the engineering teachers (96.80), technology & design (92.59%), science (86.11%), language art (83.33%), then mathematics (80.56%).

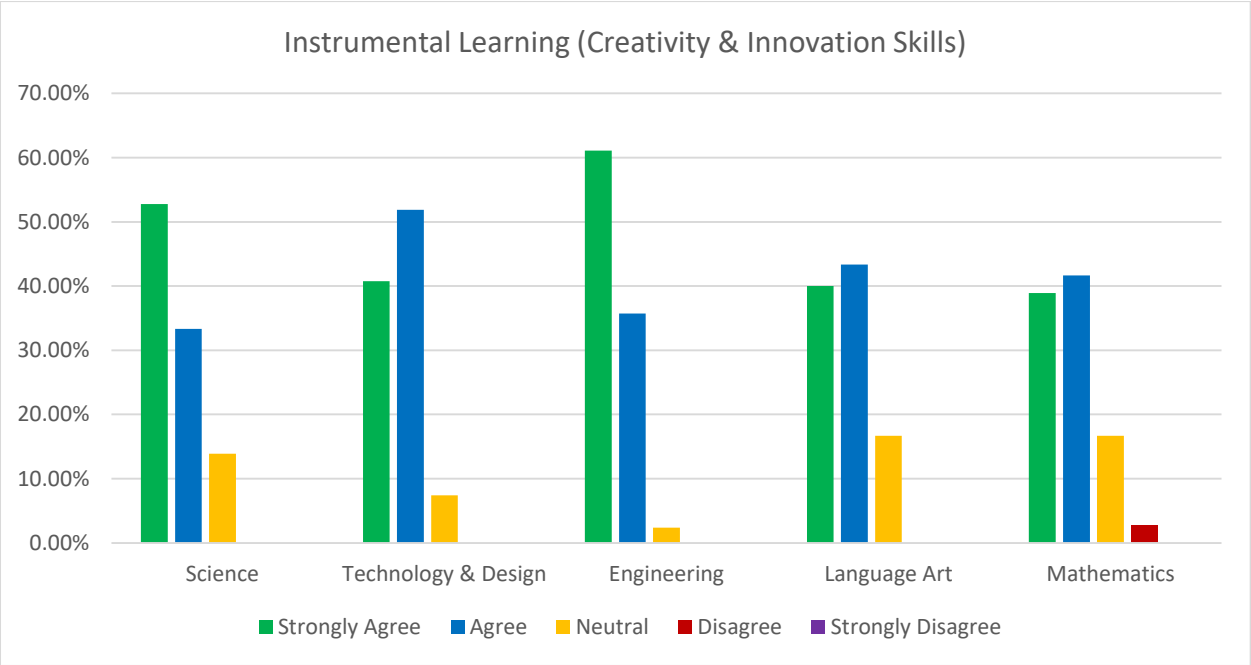

Figure (4.18): The differences between teachers' responses in instrumental learning (creativity and innovation skills) per specializations.

The highest mean of problem-solving skills of instrumental learning is 4.52 with a standard deviation of 0.67 where 90.47% of responses were between strongly agree and agree that students solve ample range of problems between well- and ill-structured.

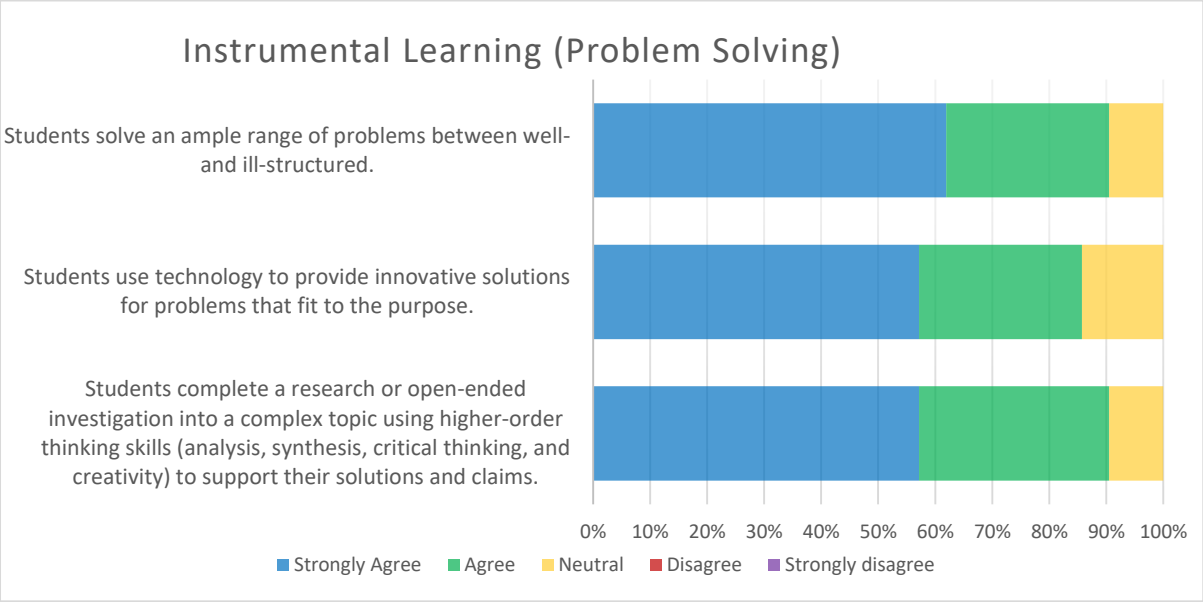

Figure (4.19): The curriculum developer responses of creativity and innovation skills in instrumental learning.

The highest mean of teachers' responses in problem-solving skills of instrumental learning was 4.40 with 0.62 standard deviation where 93.34% of teachers were between strongly agree and agree that students complete research or an open-ended investigation into a complex topic using higher-order thinking skills (analysis, synthesis, critical thinking, and creativity) to support their solutions and claims.

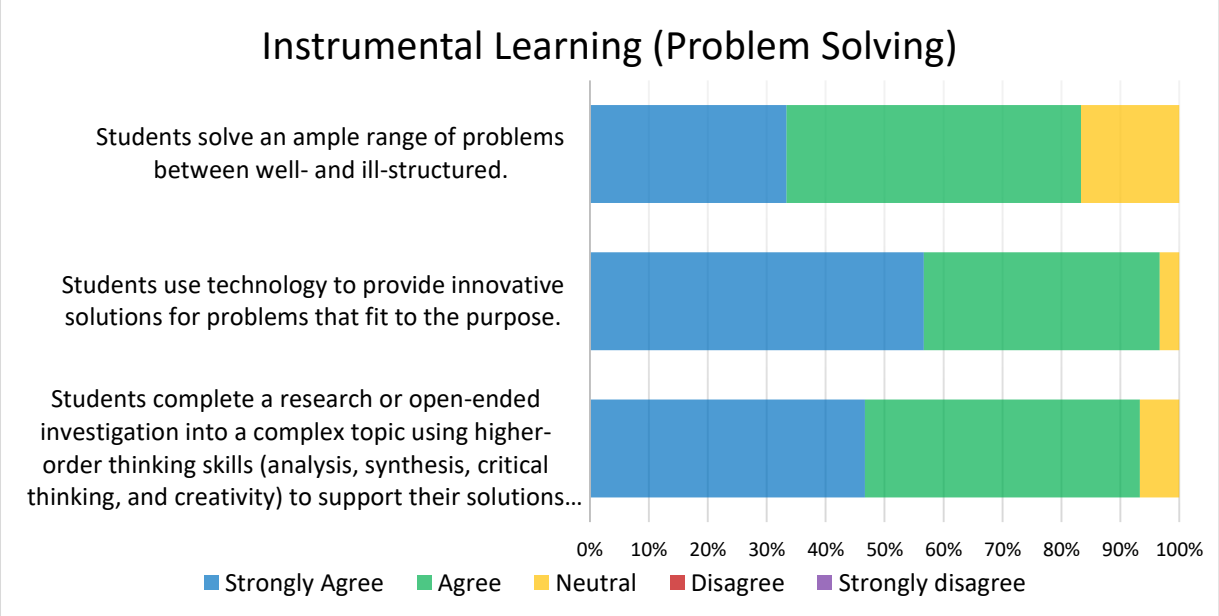

Figure (4.20): The responses of teachers in problem-solving skills of instrumental learning.

The highest rank of teachers' responses in the problem-solving skills of instrumental learning was the engineering teachers (100%), technology & design (92.60%), science (88.89%), then mathematics (88.88%).

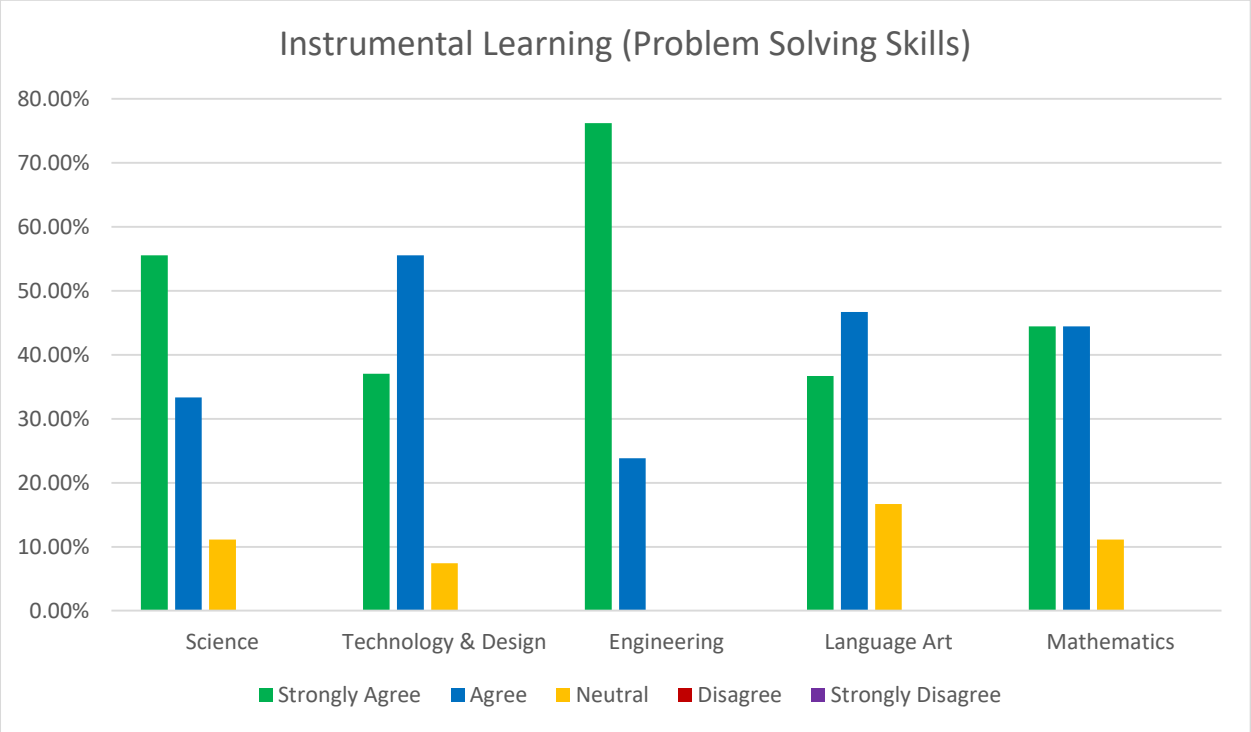

Figure (4.21): The differences between teachers' responses in instrumental learning (problem-solving skills) per specialization.

For the creativity and innovation skills, both curriculum developers and teachers stated that students can generate innovative ideas and ways of thinking in solving problems. Curriculum developers mentioned that students are open to challenges, difficulties and risk-taking. On the other side, teachers mentioned that students use extensive range of subjects' techniques as part of the creative process.

For problem-solving skills, both curriculum developers and teachers mentioned that students can solve an ample range of problems between ill- and well-structured. in addition, the emphasized that students complete a research project or open-ended investigation into a complex topic using higher-order thinking skills (analysis, synthesis, critical thinking, and creativity) to support their solutions and claims. Teachers added that students use technology to provide innovative solutions.

Communicative Learning

The highest mean of communication skills within communicative learning were found in two items where the mean is 4.66 and standard deviation is 0.577. The responses that were between strongly agree and agree were 95.24% that students can communicate using an

extensive range of methods, verbal, written, visual, and/or non-verbal; and can organize the content of their thoughts and communication into a logical and coherent whole.

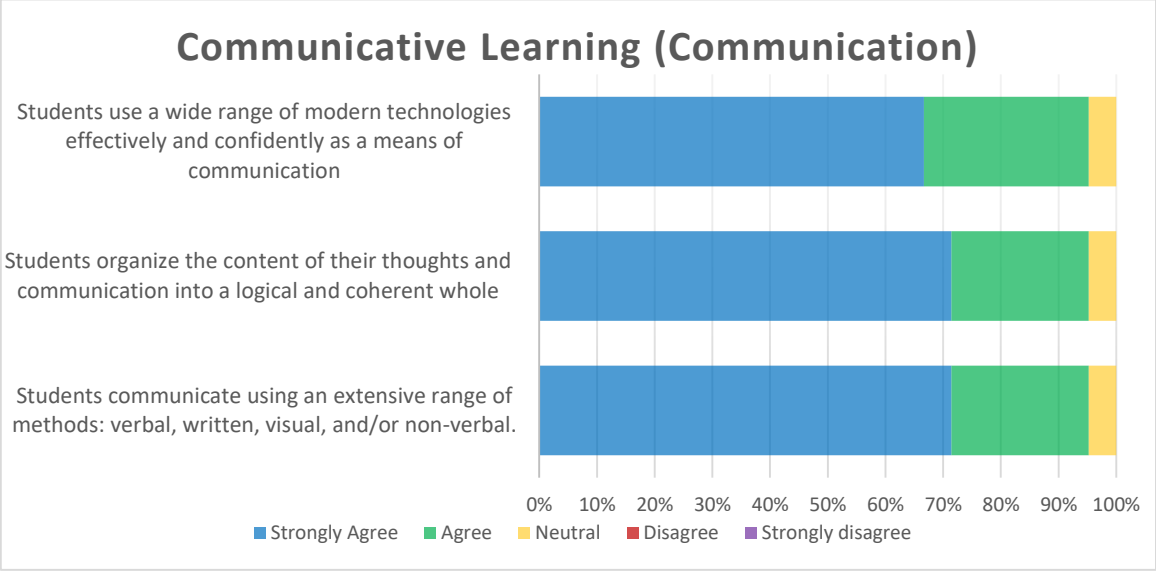

Figure (4.22): The curriculum developer responses of communication skills in communicative learning.

The highest mean of teachers' responses in communication skills of communicative learning was 4.50 with 0.57 standard deviation where 93.34% of teachers were between strongly agree and agree that students use a wide range of modern technologies effectively and confidently as a means of communication.

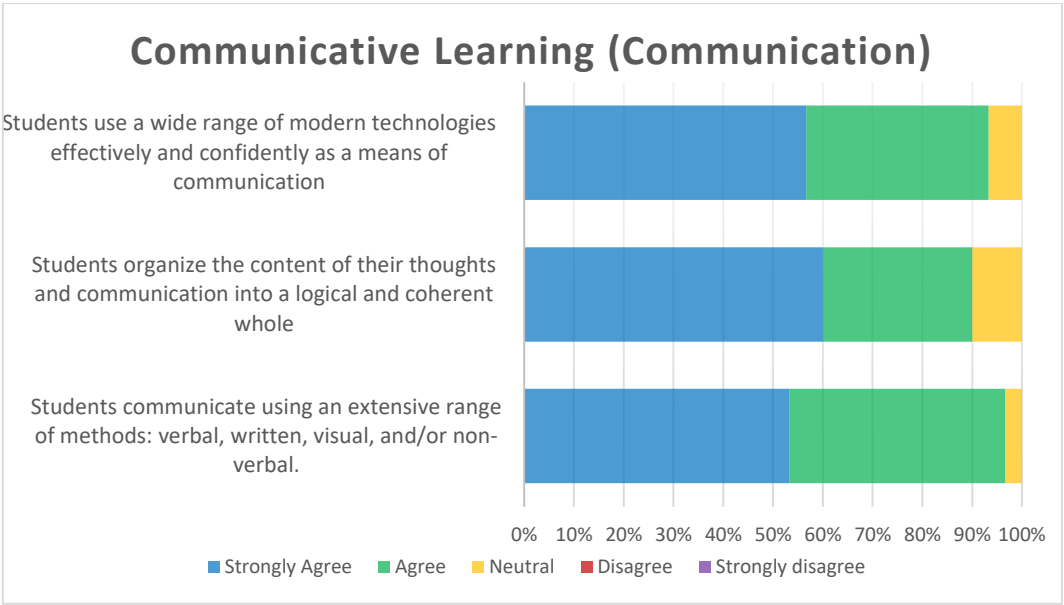

Figure (4.23): The responses of teachers in communication skills of communicative learning.

The ranking of teachers' responses in the communication skills of communicative learning was as the following: engineering (100%), technology & design (96.30%), science (94.32%), mathematics (91.66%), and language art (86.67%).

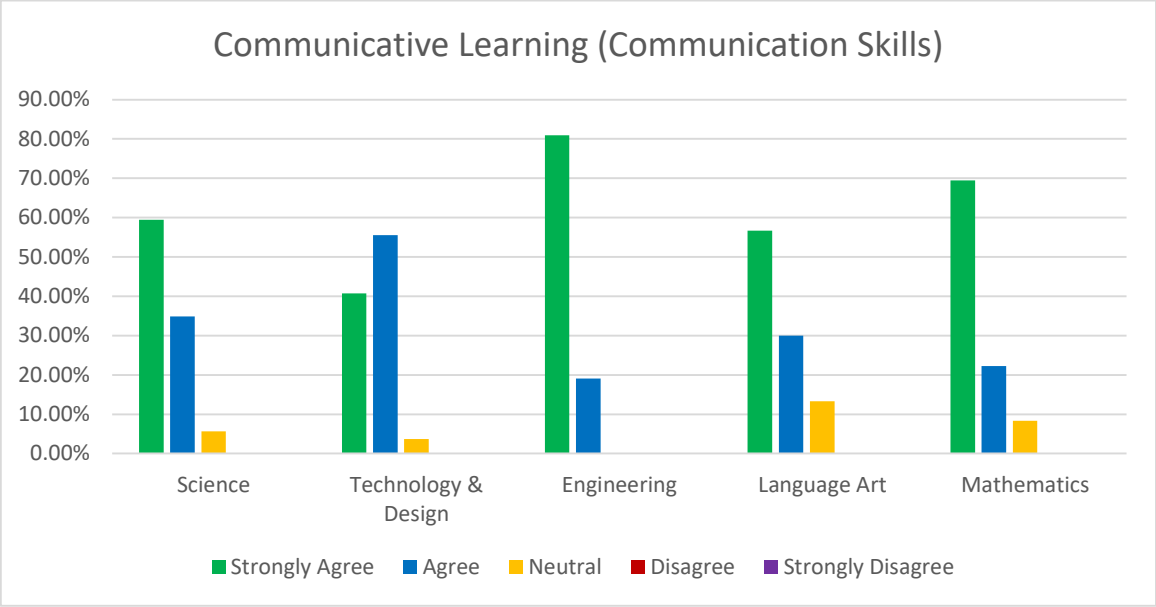

Figure (4.24): The differences between teachers' responses in communicative learning (communication skills) per specialization.

The highest mean of the collaboration skills of communicative learning is 4.61 with a standard deviation of 0.58 where 95.24% of responses were between strongly agree and agree that students can work with others to guide, counsel and motivate team members to achieve team goals.

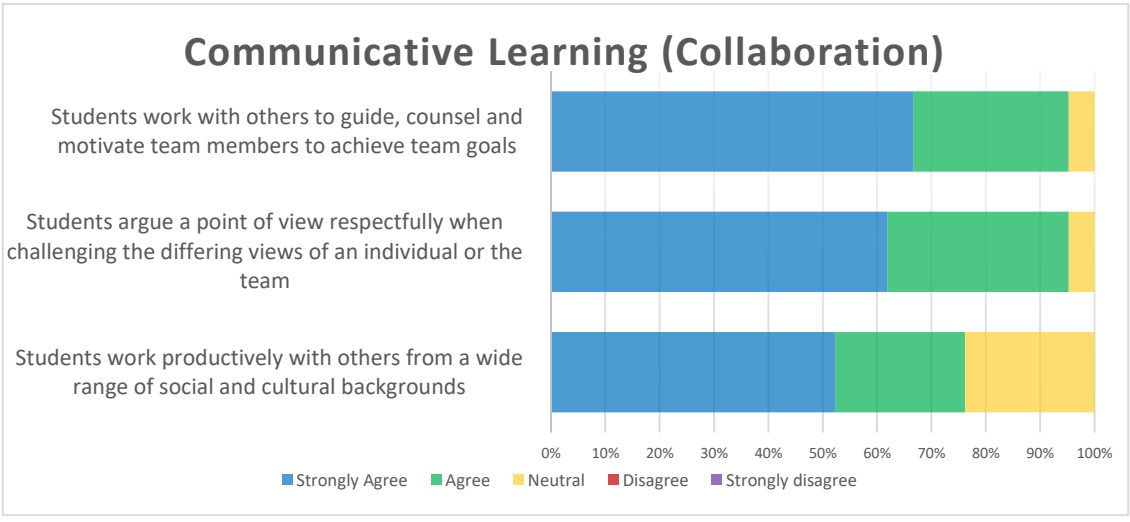

Figure (4.25): The curriculum developer responses of collaboration skills in communicative learning.

The highest mean of teachers' responses in collaboration skills of communicative learning was 4.56 with 0.62 standard deviation where 93.34% of teachers were between

strongly agree and agree that students work with others to guide, counsel and motivate team members to achieve team goals.

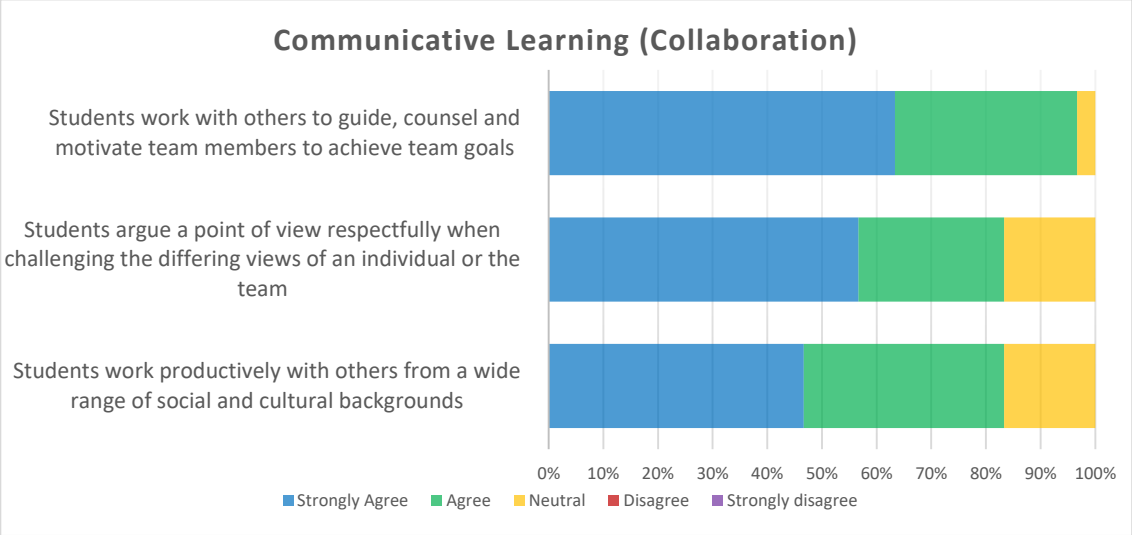

Figure (4.26): The responses of teachers in collaboration skills of communicative learning.

The ranking of teachers' responses in the collaboration skills of communicative learning was as the following: engineering (92.86%), technology & design (88.89%), language art (86.67%), science (86.11%), and mathematics (83.33%).

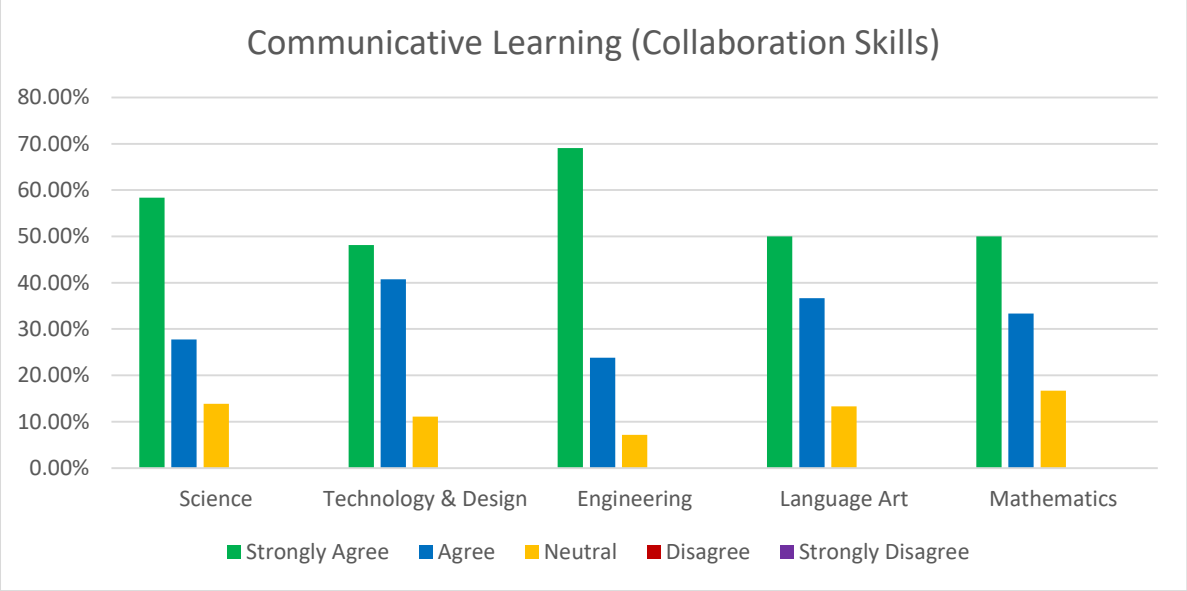

Figure (4.27): The differences between teachers' responses in communicative learning (collaboration skills) per specializations.

The highest mean of self-direction skills was in two items with a value of 4.66 and standard deviation of 0.65. The percentage of the responses was 90.48% where students can initiate a range of simple and complex activities and tasks which advance their knowledge, understanding and skills; and recognize opportunities for self-advancement and opportunities that will benefit others.

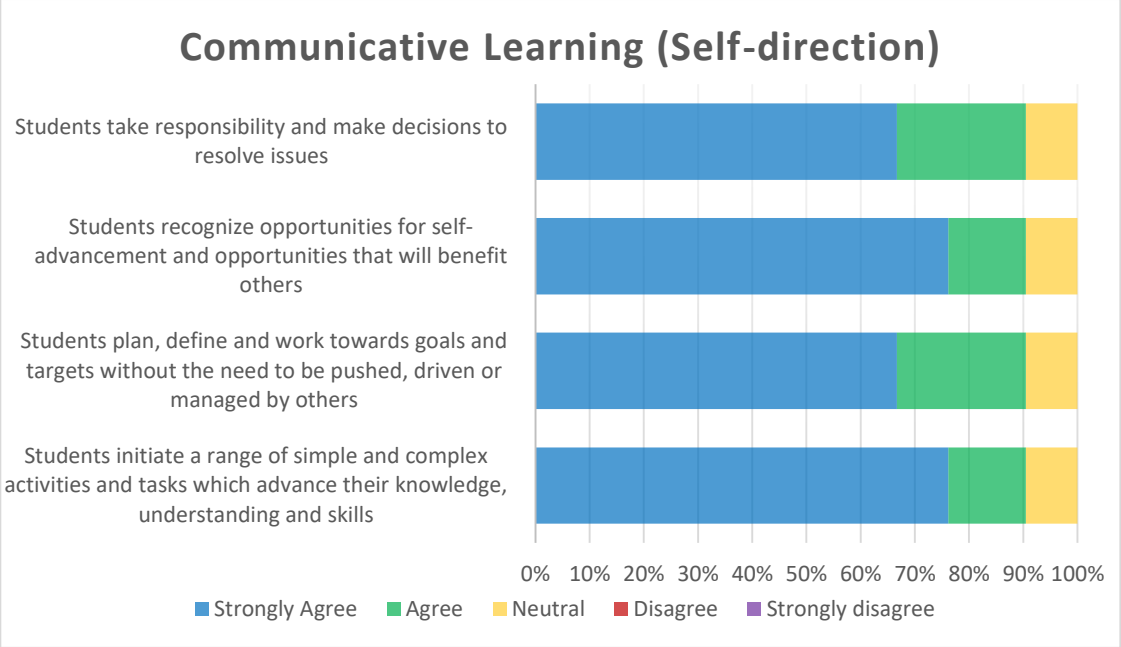

Figure (4.28): the curriculum developer responses of self-direction skills incommunicative learning.

The highest mean of teachers' responses in collaboration skills of communicative learning was 4.40 with 0.67 standard deviation where 90% of teachers were between strongly agree and agree that students take responsibility and make decisions to resolve issues.

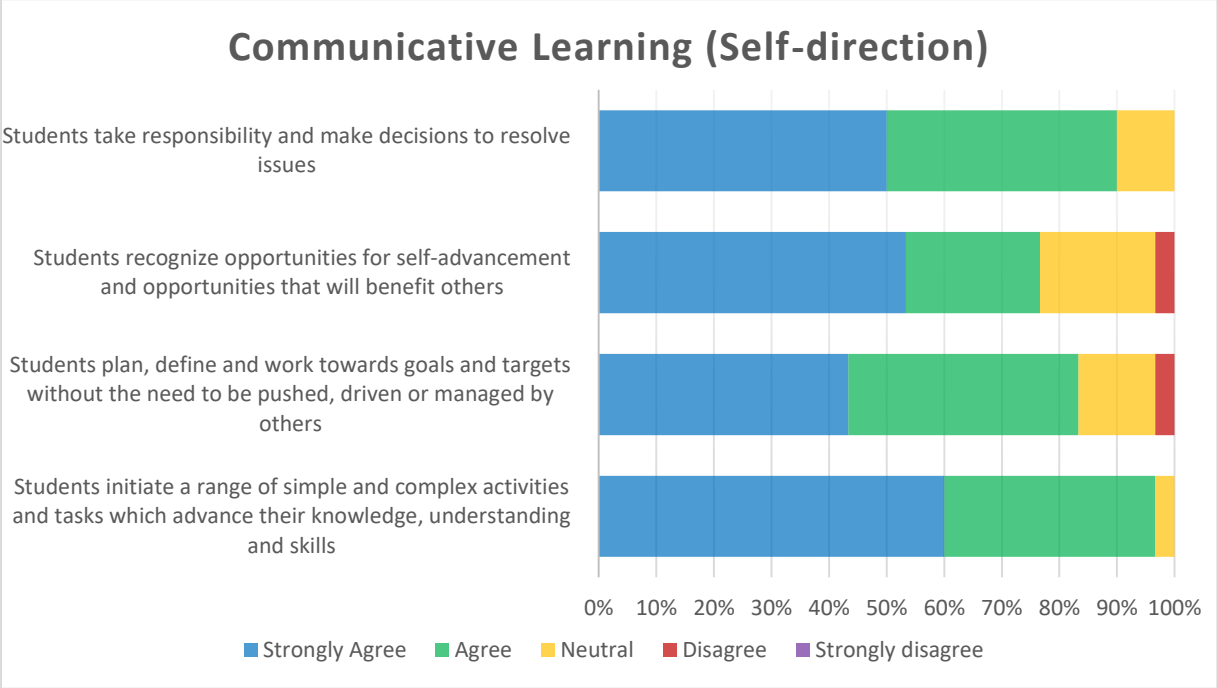

Figure (4.29): The responses of teachers in self-direction skills of communicative learning.

The ranking of teachers' responses in the self-direction skills of communicative learning was as the following: engineering (96.43%), science (91.67%), technology & design (91.66%), mathematics (83.33%), and language art (80%).

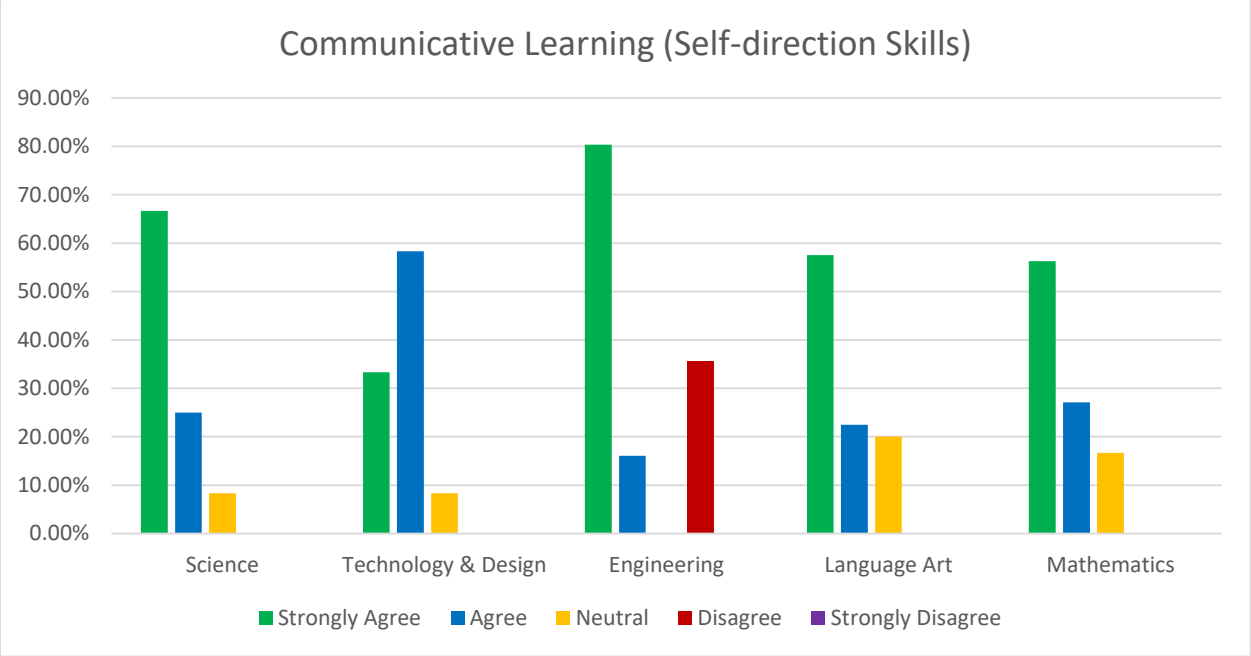

Figure (4.30): The differences between teachers' responses in communicative learning (self-direction skills) per specialization.

For communication skills, curriculum developers and teachers agreed that students communicate using an extensive range of methods: verbal, written, visual, and/or non-verbal. In addition, they added that students organize the content of their thoughts and communication into a logical and coherent whole. Teachers added that students used a wide range of modern technologies effectively and confidently as a means of communication.

For collaboration skills, curriculum developers and teachers pointed out that students work with others to guide, counsel, and motivate team members to achieve team goals. Curriculum developers added that students argued a point of view respectfully when challenging the different views. On the other side, teachers added that students work productively with others from a wide range of social and cultural backgrounds.

For self-direction skills, curriculum developers and teachers stated that students take responsibility and make decisions to resolve issues. Curriculum developers added that students plan, define and work towards goals and targets independently; and initiate a range of simple and complex activities and tasks which advance their knowledge, understanding and skills. Teachers added that students recognize opportunities for self-advancement and opportunities that will benefit others.

4.4.3 Participants' Perceptions (Qualitative Results)

This section consists of three open-ended questions. These questions aim to shed light on participants' deep meanings of perceptions and further support the quantitative results. The results represent the three questions and the responses of curriculum developers followed by teachers' responses.

The impact of students' feedback

Q1: What is the impact of the feedback given to students and what is the duration between each set of feedback?

The curriculum developers had high expectations about students' learning. They responded that the feedback has a great impact on students' work and changes their perspectives during the learning process. Students become aware of their strengths and weaknesses. In addition, when the feedback is given to students earlier it becomes more beneficial for adapting their goal settings, that in turn meets the desired outcomes for the tasks.

The teachers' responses vary about the feedback, however, most of them emphasize the importance of the immediate, earlier and continuous feedback given to students that helps in understanding their strengths and weaknesses, improves their work, changes their points of view, and adjusts their learning processes.

Other teachers' responses that are considered important were as the following:

Teacher 1: "*Constructive feedback provides students a big chance to redirect their progress and reminds them of small/big points that lead to the correct path. Feedback should be provided frequently for students and directly after assessing their learning in order to correct their mistakes as early as possible.*"

Teacher 2: "*Feedback should impact the way students look at their goals and alter their mindset if needed to guide them in the right direction. This feedback should be given frequently, probably on a weekly or bi-weekly basis.*"

Teacher 3: "*Feedback is motivating and improving the performance of many students who have a better sense of responsibility and who are really eager to learn. Feedback was given after every summative or formative assessment.*"

Teacher 4: "*The feedback should align with the task and the duration would depend on the student product. For example, if you are assessing the fidelity and/or complexity of student research, then the feedback should be singularly focused on that, while the duration of the feedback should be as immediate as possible but take no longer than 48 hours.*"

Teacher 5: "*The impact is that the feedback allows students to address any targeted issues present in their body of work. Duration depends on the scope of the task. 1-2 weeks should be sufficient.*"

Teacher 6: "*Feedback is crucial - it completes the teaching process. It helps to overcome whatever abstract or theoretical point a teacher is making and makes it concrete and memorable for the student.*"

The challenges in a transdisciplinary STEAM curriculum using authentic assessment

Q2: What are the challenges you face in designing lesson plans using transdisciplinary curriculum and authentic assessment?

The most challenging aspect they face is the alignment between the curriculum standards and the country's vision. Some responses reported that designing a variety of activities that are authentic, target the same objectives, and lead to transform students' learning set as another challenge. Other responses were as the following:

Participant 1: "*The biggest challenge is the time consumed in searching for the suitable topics for students that match their levels of readiness. In addition, differentiation between tasks given to students in order to suit their different levels.*"

Participant 2: "*There needs to be co-teaching with the other discipline teachers in order to make sure proper material is being used. Also, in order for this to be successful, teachers need to be teaching one prep (grade level) to focus on the student needs.*"

The biggest challenge they face is the time needed to cover the curriculum in depth in addition to designing a variety of tasks that target the same desired outcomes. Other responses from teachers were as the following:

Teacher 1: "*The frenetic testing that goes on in our school system requires teachers to teach at breakneck speed. In return teachers rarely find the time to collaborate with other teachers from other disciplines.*"

Teacher 2: "*Designing such plans takes a longer time and requires very effective and efficient communication between teachers of different subjects. There is also the lack of experience of most teachers in the topics of transdisciplinary activities.*"

Teacher 3: "*Material may have to be created from scratch after researching best practices and surveying the learners in the room. Authentic assessment needs to be efficient, as there are cultural norms that may affect the way of a planned piece of work."*

Teacher 4: "*Use more focused assessment techniques to integrate the maths subject with the requirements of the other subjects. Sharing resources across departments.*"

The teachers added that designing and planning the graduation projects were easier, effective, and not time consuming like the courses' planning. This is because they co-plan the graduation projects with their students and get ideas from them.

The advantages in a transdisciplinary STEAM curriculum using authentic assessment

Q3: In your opinion, what are the advantages of designing a transdisciplinary curriculum using authentic assessment?

Most of the responses stated that the development of students' skills in order to prepare them for careers that do not yet exist is the most advantage. In addition, changing their perspectives of how they view the world is another advantage. Other responses were as the following:

Participant 1: "*The advantage is in developing students' higher-order thinking skills and they will explore the impact of their learning on how they view the world.*"

Participant 2: "*If there is enough time, it will be a precious learning process that develops students to be independent and innovative thinkers… but our dense curriculum, compounded by students' lack of language comprehension and limited time* does not *allow for such learning."*

Participant 3: "We as teachers are benefiting from the collaboration we do in order to design the STEAM lesson. We benefit from each other through sharing experiences and viewing others' perspectives."

The responses to this question vary from one teacher to another, however, most responses were that the advantage is in developing students' higher-order thinking skills; helping them to explore different areas; they will have deeper understanding of the concepts; will be able to connect their learning to the real world; improving critical thinking skills and their way of viewing the world; and allowing them to learn more content in less time. Other important responses were stated by the teachers as the following:

Teacher 1: "*It makes the subject more interesting, keep the students engaged where teacher teaches the idea from different aspects, in addition to the integration happening with other subjects.*"

Teacher 2: "*For many years I've taught and collaborated with other teachers, and the advantages are endless. The primary advantage in my opinion would be that it allows students to synthesize knowledge and see how information is related and works together in the real world.*"

Teacher 3: "*In the long run it will create a new generation who are better at independent learning and that are assessed based on their true abilities regardless of how well they can do at standardized tests, which in my opinion overlook many factors that can have a great effect on the students' performance.*"

Teacher 4: "*The advantages can include a more integrated understanding of a concept as it relates not only to a single subject, but to any other subject area to which the given concept applies. Authentic assessment allows for real-world application of concepts making them less abstract and tangible enough for students to see the importance of that concept.*"

Teacher 5: "*Help students to understand the connection to the real world. Keep students engaged through making learning effective/fun and varied. To improve the classroom environment by collaborative learning. To use more technology in the classroom and integrate skills into creative activities*".

Teacher 6: "*Implementation of such assessments shows that the institute are using cutting-edge teaching protocols to give their students the best chance of success both in school and afterwards.*"

4.5 Summary of the qualitative Results

The table below shows the integration of the quantitative and qualitative results of: curriculum developers and teachers' questionnaire (open- and closed-ended items), lesson plans' analysis, and students' focus group results. The results are categorized in the table below based on the Know, Do, and Be (KDB) model of Drake (2010).

KNOW			
Categories / participants	**Curriculum Developers**	**Teachers**	**Lesson Plans Analysis**
Curriculum & Assessment	All agreed on giving instructions and guidelines for students in order to ensure the completion of the requirements. The integration between disciplines allows for more concepts to be taught in less time and at higher levels. Students' engagement and active learning is high through the design of transdisciplinary curriculum using authentic assessments.	Shifting from STEM to STEAM allows students to think divergently where each creates a different product based on their points of view. Authentic assessments take time at both creation and grading stages.	The lesson plans of the courses and the graduation projects show high level of knowledge where the focus is on the concepts, enduring understanding, generalizations, and principle and theories. The degree of integration is designed to be the strongest integration which is known as the third way of Dugger and Fellow's (2011) framework. It lies in integrating all subjects (science, technology, art, and mathematics) within the engineering courses and graduation project. The assessments were authentic tasks in the shape of projects, real-life problems, performance tasks, etc.
DO			
Emancipatory Learning	**Curriculum Developers**	**Teachers**	**Lesson Plans Analysis**
Critical Thinking	Students reflect on their own beliefs, values, and points of view from local and global perspectives; the design of transdisciplinary curriculum using authentic assessment allows for logical connection between ideas, contents, concepts, and areas of learning.	Students gather, evaluate, and synthesize information from different sources. Students reflect on their own beliefs, values and points of view from local and global perspectives.	They discussed the connection of the mechanical and electrical parts of their work and its value in their lives. They used their own journals/IPads where they go through the meaning of the hypothesis and the reasoning behind including this in their projects. They recorded the collection of data and its analysis through using their mathematical and analytical skills. In addition to these assessments, the robotics lessons also used performance tasks and journals as essential assessments. The process of the projects was discussed with the students and raising awareness about the stages of the projects took place.
Independent Learning	Students can set clear and challenging targets that can consistently be achieved and adapted in the light of experience. Students can reflect and evaluate their own learning and outcomes of that learning. Students use extensive range of resources and technologies independently.	Students use an extensive range of resources and technologies independently. Students reflect and evaluate their own learning and outcomes of that learning.	

Students' Reponses			
	Student stated that they were engaged in critical reflection and discussion of feedback that allow them to redirect their learning based on their assumptions. They receive feedback from their peers and teachers in addition of reflecting on their own beliefs, values and points of view where they evaluate their own learning. Students felt the change in their assumptions between the way of thinking before and after their learning. They felt change in their perspectives where they felt the values they gained and made them change their points of view. The change in their behaviors occurred when they stated that they have to revise their assumptions.		
Instrumental Learning	**Curriculum Developers**	**Teachers**	**Lesson Plans Analysis**
Creativity & Innovation	Students are open to challenges, difficulties and risk-taking. Students can generate innovative ideas and ways of thinking in solving problems.	Students use an extensive range of subjects' techniques as part of the creative process. Students generate innovative ideas and ways of thinking in solving problems.	They organized their work while solving complex problems and interconnect between divergent and convergent thinking in order to get the right route to follow. They used their previous learning and transferred it into new situations. There is enough variety and choice of activities to address diverse learning needs and are aligned to the culminating assessment and KDB model. Students are leading the learning process where they have to identify the problem, suggesting ideas; discussing the freehand drawings, research; complete AutoCAD drawings; formulate surveys; and present their plans.
Problem-Solving	Students can solve an ample range of problems between well- and ill-structured. Students complete a research project or open-ended investigation into a complex topic using higher-order thinking skills.	Students use technology to provide innovative solutions. Students solve an ample range of problems between well- and ill-structured. Students complete a research project or open-ended investigation into a complex topic using higher-order thinking skills (analysis, synthesis, critical thinking, and creativity) to support their solutions and claims.	
Students' Responses			
	Students solve complete real-life problems and create innovative projects through the authentic assessment tasks. They were identifying the problems, planning, and designing the projects, creating and innovating ideas. They used journals/IPads to record their steps and reflect on their learning. Students used different skills such as: synthesizing, analyzing, and thinking critically and creatively. They were open to challenges, difficulties and risk-taking. Students felt the change in their assumptions through the discussions they engaged in with their peers that changed the way they view things. They changed their perspectives due to the immediate actions taken after classroom discussions and discussions with experts. Students changed their behavior as they were eager to learn and felt responsible to benefit their country.		

Communicative Learning	Curriculum Developers	Teachers	Lesson Plans Analysis
Communication	Students can organize the contents of their thoughts and communication into a logical and coherent whole. Communication by students using an extensive range of methods.	Students communicate using an extensive range of methods: verbal, written, visual, and/or non-verbal. Students organize the content of their thoughts and communication into a logical and coherent whole. Students use a wide range of modern technologies effectively and confidently as a means of communication.	In the main part of the lesson where the activities are introduced, students are instructed to work actively in groups to complete their tasks. For example, students should work together to have at least four ideas that will be approved by the instructor. In addition, it was planned that they have to teach each other and clarify concepts when needed within their groups. The latest mechanical machines were provided to students, with special trainers and experts. Students have the opportunity to experience different careers through their projects and have help in the completion of their projects. Dialogues between students to students and students to teachers were mentioned in the plans in order to give opportunity to feedback, reflect critically, and change their perspectives.
Collaboration	Students work with others to guide, counsel, and motivate team members to achieve team goals. They argue a point of view respectfully when challenging the different views.	Students work productively with others from a wide range of social and cultural backgrounds Students work with others to guide, counsel and motivate team members to achieve team goals	
Self-direction	Students initiate a range of simple and complex activities and tasks which advance their knowledge, understanding and skills. Students plan, define and work towards goals and targets independently; and take responsibility and make decisions to resolve issues.	Students recognize opportunities for self-advancement and opportunities that will benefit others. Students take responsibility and make decisions to resolve issues.	
Students' Results			
	Students were self-directed learners who lead the learning process. They communicated information accurately, clearly, and confidently. Students communicate using an extensive range of methods: verbal, written, visual, and/or non-verbal with their peers, teachers and experts. They argue a point of view respectfully when challenging different views. In addition, they used a wide range of modern technologies effectively and confidently as a means of communication. Female students pointed out the change in their assumptions where they felt adding art within their projects increased their interests toward scientific subjects while males mentioned that they change their assumptions when they were engaged in		

	challenging tasks. Females changed their perspectives about the scientific subjects where they stated that they were more interested in completing their projects to produce artistic product while males changed their perspectives due to the feedback they received from their peers, teachers and experts. Both males and females changed their behaviors when they felt proud of their achievements and how they act as adults in their jobs for serving the community.	
Open-ended Responses	**Curriculum Developers**	**Teachers**
The Impact of Feedback	They responded that the feedback has a great impact on students' work and changes their perspectives during the learning process. Students become aware of their strengths and weaknesses especially when feedback is given to them earlier; it becomes more beneficial for adapting their goal settings that in turn meet the desired outcomes for the tasks.	The lead teachers' responses were that students become aware of their strengths and weaknesses and feedback should be given earlier in order to give them opportunities to improve their work. The teachers' responses vary about the feedback; however, most of them emphasize the importance of the immediate, earlier and continuous feedback given to students that help in understanding their strengths and weaknesses, improve their work, change their points of view, and adjust their learning process.
Challenges of designing transdisciplinary curriculum & authentic assessment	The primary challenge they face is the alignment between the curriculum standards and the country's vision. Some responses reported that designing a variety of activities that are authentic and lead to transform students' learning is another challenge. They find it very time consuming to search for suitable topics for students that match their levels of readiness. In addition, differentiation between tasks given to students in order to suit their different levels.	The biggest challenge they face is the time needed to cover the curriculum in depth. Other responses were about the wide range of designing multi tasks that target the same objectives.
Advantages of designing transdisciplinary curriculum & authentic assessment	Most responses stated that the development of students' skills in order to prepare them for careers that do not yet exist is the biggest advantage. In addition, changing their perspectives of viewing the world is another advantage. Designing transdisciplinary curriculum using authentic assessment promotes students' competencies in terms of attitudes, knowledge and skills that enhance their higher-order thinking skills.	The responses to this question vary from one to another, however, most responses were that the advantage is in developing students' higher-order thinking skills; help them to explore different areas; they will have deeper understanding of the concepts; will be able to connect their learning to the real world; improving critical thinking skills and their way of viewing the world; and allowing them to learn more content in less time.

Table (4.14): Integration of the quantitative and qualitative results of curriculum developers' and teachers' perceptions and practices.

The next chapter is the final chapter where the results of the first and second phases are discussed in more detail in the light of the literature reviewed and the study of the theoretical framework. The discussion is followed by appropriate recommendations, conclusions, and the limitations of the study.

Chapter Five: Discussion, Conclusion and Recommendations

The design of a transdisciplinary STEAM curriculum using authentic assessment in a vocational institute in UAE has a positive impact on transforming students' learning. There were two phases that fulfill the main purpose of the study. The first phase aimed to investigate curriculum developers' and teachers' perceptions and practices in designing and planning a transdisciplinary STEAM curriculum using authentic assessments, and the alignment between the transdisciplinary curriculum and authentic assessment has been investigated. The second phase is aiming to investigate the cause-and-effect relationship of the treatment (emancipatory, instrumental and communicative learning) on transforming students' learning. In addition, students' perceptions and perspectives are explored. The results of the two phases are integrated and discussed in the light of the conceptual framework of the study that involves three main categories: Know, Do, and Be. The results are discussed in the following sequence: Know (Design of STEAM curriculum using authentic assessment); Do (The impact on students' transformational learning); and Be (Variance of students' frames of reference.). Then, the implications, conclusion and recommendations, and limitations of the study are interpreted.

5.1 Know: Design of STEAM curriculum using authentic assessment

In teachers' lesson plans, it was found that the engineering courses and graduation projects have different templates; however, both of them are following the backward design. Wiggins and McTighe (2005) mentioned the stages of the backward design of the curriculum through these steps: identify the desired outcomes, assessment criteria and methods, and instructional activities that lead to transforming students' learning. These steps were used as criteria in analyzing lesson plans where the absence of one of them will exclude the lesson plan from being analyzed, and there was clear alignment between the three stages.

The analysis included the desired outcomes (enduring understanding, contents, objectives, skills, and essential questions). In addition, the assessment criteria are identified and shared with the students. The transdisciplinary curriculum is a case of curriculum innovation as it involves complex integration to deliver high quality learning experiences without neglecting academic outcomes (Tan & Leong, 2014). The results show that the curriculum is designed to have the strongest integration between the STEAM subjects while addressing global real-life problems.

Both courses and graduation projects are integrated into a curriculum where the engineering courses have a complex integration between the STEAM subjects (Robotics, AutoCAD, Electrical principles and applications). This is aligned with Dugger and Fellow's (2011) model where they proposed the highest integration as E→STM where there is overlap between subject boundaries. This is also known with different terminology, such as "reconstructed knowledge" (Beane, 1991; Vars, 1991), and Dewey (1986) promoted the term core curriculum as the reconstruction of knowledge. It is important to note that this is aligned to the conceptual framework of the study where the complex integration between the subjects allows learners to access the three types of learning (reflective, communicative and instrumental) that lead to transformative learning.

The authentic assessment tasks used in the engineering courses and the graduation project are aligned to the desired outcomes. The lesson plans of the courses and the graduation projects were focusing on the higher level of knowledge (example: enduring understanding, principles, and theories, etc.). This has been emphasized where learning requires an active mental process that allows for connection between knowledge, ideas, repetition, practice and memorization (Gettings, 2016; Gross & Gross, 2016; Howe, 1998; Liao, 2016; Steyn, 2017; Strange & Gibson, 2017).

The lesson plans of the graduation projects were designed based on students' interests, while the courses were not based on their interests. The planning and designing of the courses is aligned with the process of Drake's step-by-step planning that starts first by reading the curriculum document vertically and horizontally. Then, choose the appropriate theme and brainstorm activities. Rich assessments are created in the next step and instructional activities are created accordingly (Drake, 2007). On the other hand, the lesson plans of the graduation projects show the co-planning between teachers and students based on their interests. This is supporting Beane's (1991) approach where the planning involves students' inputs that are based on their interests. Students' roles in graduation projects are clear where they were planning, designing, and creating their own projects which affected their behaviours. Beane (1991) emphasized that using students' curiosity in planning increased students' engagement and eliminated behavioural problems. It was stated that when learners are responsible about their learning processes in authentic tasks, they promote satisfaction and positive behaviour (James & Cassidy, 2018). The design of the courses and graduation projects emphasized the alignment between the transdisciplinary STEAM curriculum and the authentic assessments where the process of learning focused on real-life situations that lies in intellectual, personal, and dialogue reflection. A study of Lewis (2017)

emphasized that the constructive alignment integrates between: the desired outcomes of authentic tasks that need to be clear and explicit; design of constructivist learning activities; and the co-construction of integrated knowledge. Bass (2014) supports this alignment where the authentic assessment tasks are described as social and cognitive pedagogies that engage learners in procedural learning processes. As stated in the literature, the authentic assessment should be established in an environment that allows students to: work, learn, create, develop a scenario, and solve problems through an instrumental learning approach; open conversation, communicate and collaborate with their peers through a communicative learning approach; and think critically, reflect on their learning, assess their learning and their peers, and provide constructive feedback through an emancipatory learning approach (Boud & Falchikov, 2005; Herrington, Reeves & Oliver, 2010; James & Cassidy, 2018; Mueller, 2010). This is also corroborated by Dewey (1997) where there is connection between reflection and actions that allows students to move back and forth in the learning process.

On the other hand, Dewey (1933) emphasized the radical student-centred design of curriculum integration that focuses on students' interest and community rather than subject areas. All curriculum developers and teachers agreed that the assessment used in designing a transdisciplinary STEAM curriculum is the authentic assessment. These results highlight the same perspective of Drake and Burns (2004) where they stated that the primary assessment concern of the transdisciplinary curriculum is the authentic assessment. In other words, the authentic assessment tasks are the best way to assess students' learning due to exposing them to real-world problems that require a complex integration of knowledge to solve them. In addition, students were provided with assessment criteria that were obvious and well-defined to them. Greenhill et al. (2018) emphasized the importance of providing students with a clear and explicit purpose, instructions and assessment criteria of what they are learning. Meyers and Nulty (2009) mentioned that the authentic assessment tasks allow students to use integrated knowledge to solve real-world problems and the use of higher-order cognitive processes that provide challenge, interest and motivation.

All participants with teaching and non-teaching positions strongly agreed that the design of a transdisciplinary curriculum using authentic assessment allows students to be active learners and engaged in their learning. In addition, all participants stated that the authentic assessment provides students with challenge, interest and motivation. This is consistent with Eubanks (2008)

who indicated that the advantages of authentic assessment increases students' motivation. Furthermore, Zilvinvkis (2015) emphasized that motivating students to be engaged in authentic assessment tasks leads to transformative learning. Similar results were shown in the current study where the authentic assessment tasks used in both courses and graduation projects show students' emancipatory, communicative, and instrumental learning, where there are several checkpoints using feedback, critical reflection, and students' discussions to argue their points of view. This is supported by Greenhill et al. (2018) who emphasized that a transdisciplinary curriculum using authentic assessment tasks cut across three types of learning (emancipatory, communicative and instrumental) that transform students' frames of reverence (habits of mind, mindsets, and perspective transformation).

There was criticism about integrated curriculum implementation where teachers and administrators couldn't recognize the quantity and quality of learning (Russell & Burton, 2000). However, it has been mentioned clearly in this study that the lesson plans included the several checkpoints where there are: self-assessment, critical reflection, feedback, discussions, etc. In addition, students were provided with the assessment criteria, instructions, and rubrics to ensure the high quality of work, as was mentioned in a study of Greenhill et al. (2018). The teachers' planning was focusing mainly on engaging students in learning; developing students' skills; ensuring the high quality of work; and students' critical reflection and feedback. This is not aligned with Dawson (2003) who argued that teacher's main focus is to produce higher test scores. The University of New South Wales (UNSW) (2017) stated that the authentic assessment aims to connect between contents and apply new knowledge into meaningful and relevant tasks; however, it requires a long time of creation and grading. This is aligned with participants' responses: they all agreed that authentic assessment takes time at both creation and grading stages; however, it allows for connection between knowledge, ideas, repetition, practice, and memorization, which is also emphasized by other researchers (Gettings, 2016; Gross &Gross, 2016; Liao, 2016; Steyn, 2017; Strange & Gibson, 2017). Herrington and Brown (2014) mentioned key important elements in designing authentic assessment tasks, while Guezy, Moore and Harwell (2016) stated similar key elements in designing the integrated curriculum where all key elements occurred in the lesson plan analysis that shows strong connection between authentic assessments and transdisciplinary curriculum.

Furthermore, the lesson plans' design was supported by Lewis (2017) who emphasized that the curriculum should be constructively aligning desired outcomes, authentic assessment, constructivist learning activities and co-construction of integrated knowledge. The key elements are identified as the following: challenge; performance tasks, transfer of knowledge, metacognition, accuracy, trustworthiness, discussion, and collaboration (Guezy, Moore & Harwell, 2016; Herrington & Brown, 2014). Furthermore, all teachers agreed that shifting from STEM to STEAM allows students to think divergently where each creates different products based on their interests. This study confirms previous research where adding art to STEM subjects allow students to think both convergently and divergently (Corply, 2015; Costantino, 2018; Gettings, 2017; Gross & Gross, 2016; Katz-Buonincontro, 2018; Perignat & Katz-Buonincontro, 2018).

In addition, most teachers agreed that integration between disciplines allows for more concepts to be taught in less time and at higher level; this also correlates favourably with other researchers (Drake & Reid, 2010; Jacobs, 1989). Sousa and Pilecki (2013) emphasized that integrating art into STEM allows for more information to be transferred into students' long-term memory that will last for a long time. All teachers agreed that students need to be provided with detailed instructions and guidelines to ensure the completion of the requirements of the authentic assessment tasks. It was found that the engineering teachers had the highest results from designing transdisciplinary curriculum using authentic assessments, followed by science, technology and design teachers, then English language teachers, while mathematics teachers had the least agreement.

5.2 Do: The Impact on Students' Transformational Learning

The results show that the design of the transdisciplinary STEAM curriculum using authentic assessment had a positive impact on students in the experimental group while there were no such results found on students in the control group. These results are supported by previous studies, which stated that the student-driven approach in a meaningful learning environment is influenced through the use of a transdisciplinary curriculum where students are engaged in authentic assessment tasks (Boix-Mansilla & Gardner, 2005; Breunig, 2017; Buck Institute for Education, 2016; Drake, Reid & Kolohon, 2014; Ghosh, 2017; Greenhill et al., 2018; Merilainen & Piispanen, 2013; Naidoo & Kirch, 2016; Turner, 2015; Vasquez, Sneider & Comer, 2013).

McTighe and Wiggins (1999) emphasized that transformative learning moves students from the stage of knowing to being able to do. It focuses mainly on the learning process where the student-centred environment is experienced. The planning of all lessons especially the graduation projects focused on learning by doing, which emphasizes the results of other studies (Gettings, 2016; Gross &Gross, 2016; Liao, 2016; Steyn, 2017; Strange & Gibson, 2017). This was indicative of the results of the current study of the three types of learning (emancipatory, instrumental and communicative) that were successfully implemented due to the alignment between the transdisciplinary curriculum and authentic assessment. The use of the three types of learning is fully compliant with Greenhill's study (2018) who emphasized that the three types of learning help to develop students' skills that lead to transformative education. The authentic assessment tasks are used in the learning plans that allow the presence of the three types of learning. The lesson plans promote what Biggs (1996) stated, that there is a strong focus on students' skills and competencies that lead the teaching and learning processes, which promote the constructivist approach. However, the focus of the lesson plans of the courses differs from the graduation projects; the lesson plans of the courses focused on three levels of skills that are identified as lower-order, discipline specific, and interdisciplinary. The focus of the lesson plans of the graduation projects were on the highest level of skills (interdisciplinary skills). Biggs and Tang (2007) explained the three stages of designing and planning the curriculum with a focus on mastering students' skills and engaging students in authentic tasks that allow for several checkpoints through continuous feedback and reflection on their learning. The authentic assessment tasks stated in the lesson plans are: journals, portfolios, self-assessment, and performance tasks. In addition, Rust (2002) emphasized the role of students' critical reflection through authentic assessment tasks in transforming their learning. Litchfield and Dempsey (2015) mentioned that authentic assessments are another form of formative assessment where students perform tasks rather than selecting answers. The authentic assessments are used as formative assessment that is used for the sake of learning where students are provided with feedback that improves their learning. Some researchers mentioned tasks of authentic assessments that are used in the lesson plans, such as: learning logs, projects, inquiry and real-life problems (Cheng, 2015; Greenhill et al., 2018; Lewis, 2017; Silveria, 2013; Snyder, 2013).

It is interestingly important to note that the assessment time allocation is designed to be aligned with the time allocation suggested by Litchfield and Dempsey (2015) where there is time

for students' activities, lecturing, assignments, authentic assessment, and traditional assessment. It was clear from the lesson plans that the authentic assessment is used as "assessment as learning" where it emphasizes the role of students in assessing their work and their peers' work. It has been mentioned by some researchers that assessment as learning allow students to be engaged in and leading their learning where they can make sense of their knowledge, relate it to prior knowledge, transfer it into new situations and master the transdisciplinary skills required (Earl, 2003; Greenhill et al., 2018; Lewis, 2017; Mutch, 2012). Warzynski and Baldwin (2014) emphasized that authentic assessment's role is to develop students' skills that will prepare them for future jobs that do not yet exist. Each section in the lesson plans involves guiding questions for teachers in order to plan the lessons properly. One of the interesting sections in the lesson plan is aligned with Warzynski and Baldwin (2014) where the focus of this section is on "STEAM/21st Century Skills". The guiding questions were interpreted in the lesson plans for teachers as the following:

How will you incorporate 21st century skills and STEAM into this lesson? How will you make connections from content to real-life applications? What concentrated examples will you use? How could you link this lesson to other subjects that the students are studying?

This finding appears to be well substantiated by Zilvinskis (2015) who stated that engaging students in authentic assessment tasks is to engage them in high impact practices that are important to transform their learning. The lesson plan analysis shows impressive results, where this section was focusing on the strong integration between subjects and the involvement of emancipatory, instrumental and communicative learning that lead to transformational learning. This is also emphasizing what Mueller (2010) reported about the authentic assessment, that it is a performance task which is related to real life where students can demonstrate meaningful application of essential knowledge and skills.

In addition, this section mentions clearly the degree of integration, where all the results show that it is the highest degree of integration that is identified by Dugger and Fellow (2011) as the third way of integration E→STAM. Yen and Hynes (2012) represented a heuristic cube that is designed for authentic assessments' validation. One side of this cube represents the cognitive domain (emancipatory learning), psychomotor domain (instrumental learning), and affective domain (communicative learning). Other sides of the cube represent the validity and reliability of the assessments. The last side of the cube represents the levels of assessments' stakes. This cube explains that the highest level of assessment stakes represents the highest validity and reliability

while the students' learning passes through the three domains as they go in depth of learning. The design of assessments in this study represent the flow of the three levels of assessment stakes as well as the three domains (cognitive, psychomotor, and affective) that occurred in the three types of learning (emancipatory, instrumental, and communicative learning) of the heuristic cube model of Yen and Hynes (2012) (Singleton, 2015). The flow of the assessment levels, validity and reliability, and depth of learning was clear in the authentic assessment tasks.

A strong correlation was found between the emancipatory, communicative and instrumental learning and students' results from the experimental groups. However, the strongest correlation was between students' emancipatory and instrumental learning that led to a strong relation between their communicative learning and their results. This is due to the reflection and feedback during the problem-solving process that led to strong relationships between their peers where they worked collaboratively, and consequently impacted their results. This was in agreement with the study of Greenhill et al. (2018) who stated that the emancipatory, communicative and instrumental learning has a positive impact on students' results where the three types of learning have strong correlation. However, it was stated that the critical reflection within emancipatory learning and rational discourse within communicative learning leads to the third stage, perspective transformation within instrumental learning (Provident et al., 2015). This result proves that the students are working back and forth during the instrumental learning where they revisit their work to improve it after receiving constructive feedback.

5.2.1 Emancipatory Learning

The emancipatory learning focuses on students' critical reflection through several checkpoints, such as self-assessment, and feedback from peers and teachers. The critical reflection refers to the self-examination and metacognitive awareness that is implemented in the sense of questioning and brainstorming how and why learners think certain things in certain ways (Cranton & Carusetta, 2004; Greenhill et al., 2018; Lewis, 2017; Owen, 2016). In the engineering courses, the critical reflection and discussion of feedback allows students to redirect their learning based on their new assumptions. Furthermore, all the graduation projects' plans involve time for students post conference where they receive feedback and set plans to improve their work. This is in addition to the regular feedback students receive from their peers and from their teachers. This is

the purposeful critical analysis of knowledge and experiences that allows learners to achieve deeper meaning and understanding (Greenhill et al., 2018; Lewis, 2017; Mann et al., 2007; Owen, 2016).

Students in the experimental group stated that they have changed their opinions about topics they had not found interesting at the beginning, after being exposed to a real-world problem, and found that they have to use their previous information from different subjects in order to solve it. This shows the transformation in their perspectives where they became open minded, understanding others' perspectives, knowing benefits, and accepting changes. However, a study of Greenhill et al. (2018) stated that students' emancipatory learning was not supported by teachers who need to focus on critical reflection. The results show three items that all curriculum developers and teachers agreed upon: students' reflection on their own beliefs, values, and points of view from local and global perspectives; students reflect and evaluate their own learning and outcomes; and students use an extensive range of resources and technology independently. These actions occurred due to the use of authentic assessment as learning where the purpose of this assessment is sustainability, as Almqvist, Vinage, Vakeva and Zanden (2017) stated.

In addition, many researchers emphasized that the aim of authentic assessment is to engage students to be critical assessors of their learning, where they are engaged in learning, monitor their progress, reflect critically on their learning, and suggest areas for improvement (Almqvist et al., 2017; Earl, 2003; Nutch, 2012). The curriculum developers agreed more than teachers about the design of the transdisciplinary curriculum using authentic assessment that allows for logical connection between ideas, contents, concepts, and areas of learning. In addition, they agreed that students can set clear and challenging targets that can be consistently achieved and adapted in the light of experience. In fact, there are common key elements between the transdisciplinary curriculum and authentic assessment that are identified as the following: challenge, performance or outcome product, transfer of knowledge, metacognition, accuracy, fidelity, discussion, and collaboration (Ashford-Rowe, Herrington & Brown, 2014; Guezy, Moore & Harwell, 2016). On the other hand, teachers were more agreed that students gather, evaluate, and synthesize information from different resources which emphasizes the statements of Ashford-Rowe et al. (2014) and Guezy et al. (2016) that there is development of independent learning and critical thinking skills within emancipatory learning.

The students of the experimental group were involved in authentic assessment tasks that promote emancipatory learning through reflecting and getting feedback that focuses on self-improvement and personal goals (cognitive domain) (Beghetto, 2005; Beghetto & Kaufman, 2010; Black & William, 2006; Brookhart, 2010). Students in the experimental group agreed that they can recognize problems they might face in order to accomplish their goals. On the contrary, students in the control group found difficulty in recognizing problems they might face. Students in the experimental group define constraints of the problems and set clear and challenging targets to be achieved, while students in the control group cannot do it and most of them found difficulty in setting clear challenging targets for themselves. These results are compatible with Greenhill et al. (2018) who reported that students are independent learners where they can recognize the problems they might face, setting plans to solve, and creating new products. They stated that their previous experiences affect the way they think of the problems. Interestingly, Kolb (1984) stated that the true knowledge is created through learners' experiences. However, Dewey (1938) pointed out that learners learn by reflecting on their experiences which consequently transforms their feelings and attitudes into purposeful actions. Furthermore, they reflect on their own beliefs, values and points of view from local and global perspectives. In addition, they reflect and evaluate their own learning and outcomes of that learning. This supports the fact that transformative learning occurred where students frames of reference are changed, which is aligned with the results of previous studies (Ghosh, 2017; Greenhill et al. 2018; Lewis, 2017).

Although there is no significant difference between males and females, they have different perspectives. Male students stated that they did not only think about how to solve the problem but also thought about the consequences of any solution. In addition, they mentioned that the way each one of them views the problem and tries to think of solutions is different than the others and it was based on their different previous experiences. This in turn allows them to know how to approach the world. This has been evidenced by other researchers who stated that the main function of reflection in the learning process is to connect between learning and previous experiences, knowledge, and ideas (Dewey, 1910; Kolb, 1984; Robert, 2012). Furthermore, research on how brain works has reported that the brain's natural way of extracting meaning and integrating new knowledge with prior knowledge is by comparing new experience with prior experience (Jensen, 2008; Ross & Olsen, 1993).

On the other hand, female students stated that they experienced a new environment that required collaboration and support from each other. This is not only improving their ways of thinking but also changing their habits and mindsets about how to view the world. They added that the most interesting thing for them was that each one of them knew her strengths and weaknesses which helped them to distribute the tasks accordingly. This is supported by the results of previous studies that stated that critical reflection is an essential element of transformational experiences where learners are aware of their strengths and weaknesses (Greenhill et al., 2018; Lewis, 2017; Mezirow, 1978; Saudelli, 2012; Taylor, 2007; Villarroel et al., 2017) where metacognition and constructivist learning are common practices (Baviskar, Hartle & Whitney, 2009). They felt the difference and change while they were reflecting on their work by the end of each tasks and how they changed their perspectives based on the feedback received from peers and teachers. These results confirmed the teachers' perceptions about the importance of the immediate feedback and reflection to students. These findings contradict other research findings where it was mentioned that most teachers are not trained to guide students for reflective practices, with the result that the curriculum might be covered in breadth but not in depth (Singleton, 2015).

Both males and females of the experimental group felt the value behind this change, where some of them changed their perspectives while others solidified their points of view. This has been evidenced from other researchers who stated that the intellectual and affective activities that learners engage in allow them to explore their experiences and reflect on them in order to construct new understanding (Boud et al., 1985; Gidcumb, 2016; Greenhill et al., 2018; Lewis, 2017). Students emphasized the role of reflection, evaluation and feedback through continuous discussions where they ensured that they are achieving their goals successfully. The feedback students receive from the experts in the same field was the thing that most made them change their points of view. This is the transformative learning outcomes that have been clarified by other researchers who stated that there are different levels of reflection from surface descriptions to deeper analysis and synthesis (Ballantyne et al., 2010). All students agreed that they have to revise their assumptions from time to time in order to get the solutions that have the best consequences. Desautel (2009) emphasized this finding in which the self-reflection tasks enrich learners with self-awareness and make the process more explicit, in addition to the development of metacognitive and critical thinking skills. It was also stated that students develop their skills (collaboration, communication, critical thinking, creativity, innovation, and self-direction skills)

while solving real-world problems that require integrated STEAM subjects (ElSayary, 2017; ElSayary, Forawi & Mansour, 2015).

5.2.2 Communicative Learning

Students believed in the change that occurred because they feel the value and saw the positive results of this change. It is important to highlight that communicative learning is a form of learning that involves the interpreting of values, feelings, intentions, moral decisions and normative concepts (Mezirow, 2003; Diduck & Mitchell, 2003). The students' results are affected by the communicative learning due to the interaction, discussion, and communication between students while working on their tasks. A study by Gross (2016) stated that the authentic assessment tasks within a transdisciplinary STEAM curriculum enhanced students' transformational learning where communicative learning took place and students were able to create projects that went far beyond their expectations. Students when working collaboratively produce innovative ideas to solve real-world problems. One of the results reported by Strong et al. (1995) was that students are more motivated in learning through the relationship and involvement with others in solving their problems.

The communicative learning focuses on students' interaction, communication and collaboration in completing their tasks. This is aligned with Fook and Sidu (2013) who emphasized the use of integrated knowledge in solving real-world problems and using assessment to diagnose students' abilities and progress towards achieving the desired outcomes. Communicative learning occurred in the lesson plans of both graduation projects and engineering courses. In engineering courses, communicative learning occurs in students' collaborative work and during their communications with their peers, teachers and experts. In addition, the laboratory work allows students to be self-directed learners. However, communicative learning in graduation projects occurs where students are leading the learning process: they have to identify the problem; suggest ideas; discuss the freehand drawings, research; complete AutoCAD drawings; formulate surveys; and present their plans. This is supported by a previous study that emphasized the peer group dialogue that was an implication of the work that alternates between the whole class activity and students' discussion in small groups (Black et al., 2011). This is the rational discourse that refers to the meaningful communications with others in a process of specific dialogue that develops

learners' communicative competence through negotiating their own purposes, values and meanings rather than accepting those of others (Mezirow, 1981; 1997). In addition, the awareness of others' assumptions, purposes and intentions is considered to be an important aspect of communicative learning (Owen, 2016). The experimental group of students communicated information accurately, clearly, confidently and as intended. However, the control group students faced difficulty in this which proves that the authentic assessment tasks provide students with opportunities to communicate information effectively and accurately through the continuous feedback and reflections.

All curriculum developers and teachers agreed that students can organize the contents of their thoughts and communicate them into a logical and coherent whole. In addition, all participants agreed that students communicate using an extensive range of methods: verbal, written, visual, and/or non-verbal. This is compatible with a previous study that emphasized the dialectical discourse to validate new meaning perspectives (Greenhill et al., 2018). Furthermore, all participants agreed that students work with others to guide, counsel, and motivate team members to achieve their goals. Also, they plan, define, and work towards goals and targets independently and make decisions to resolve issues. This is evidenced by Quinn & Sinclair (2016) who reported that the learning outcomes are categorized in three main points: insight to one's own values and interests; insight into values and interests of others; and insight into shared values and goals. Teachers' responses were reflecting the actual learning happening inside the classrooms where they agreed more about the high communication, collaboration and self-direction skills that occurred in their learning. Teachers emphasized that students work productively with others from a wide range of social and cultural backgrounds. This concurs well with curriculum developers who had higher expectations of students, that they argue a point of view respectfully when challenging different views. These values correlate fairly well with Singleton (2015) who emphasized that the quality of life is dependent upon the relationships with environments, communities and personal relations where students used integrated STEAM knowledge to solve real-life issues. It has been mentioned also by teachers that students recognize opportunities for self-advancement and opportunities that will benefit others. They take responsibilities and make decisions to resolve issues. This is in agreement with previous researches who stated that the outcomes of transformative learning are to act differently, having a deeper self-awareness, being

open minded, thinking of global benefits, and experiencing a deep shift in worldview (Greenhill, 2018; Saudelli, 2012; Stuckey, Taylor & Cranton, 2013).

The experimental group of students used a wide range of modern technologies effectively and confidently as a means of communication while the control group felt difficulty in doing that. This is confirmed by most teachers who stated that students use a wide range of modern technologies effectively and confidently as means of communication. These results align with previous studies where learners used e-portfolios to record their work and communicate with each other (Greenhill, 2018; Lewis, 2017). On the other hand, the curriculum developers' responses differ from this regarding students' collaboration, where they all agreed that students argue a point of view respectfully when challenging the different views. The experimental group of students work productively with others from a wide range of social and cultural backgrounds while some students of the control group had difficulty. Furthermore, the experimental group of students mentioned that they plan, define and work towards goals and targets independently. This correlates with the results of previous studies that stated that students become independent, self-directed learners, and work smoothly with others while arguing their own points of view (Hunter-Doniger & Sydow, 2016). Students work with their peers to find alternative solutions to the problems and argue a point of view respectfully when challenging the different views of an individual or a team. This is the relational knowing that is defined as the awareness of relationship with the community and the world (Riley-Taylor, 2004). On the contrary, the majority of the students in the control group stated that they work with their peers to find alternative solutions to the problems, but they lacked planning, defining problems and working towards goals independently.

The experimental group of students stated the importance of the discussion and communications done with their peers and how this changed their perspectives. Singleton (2015) emphasized that the quality of life is dependent upon relations with environments, communities, and with personal relations. It is important to note that the control group of students are not aware of their weaknesses and strengths as well as that they do not set goals for themselves to achieve. Finally, the experimental group can connect between ideas with their peers to find the most suitable way of solving problems. This is the divergent thinking which is emphasized in a similar study by Hunter-Doniger & Sydow (2016). They emphasized that the communication with their peers who have similar interests was advantageous where they started to think of fruitful ideas that benefit their community. Previous studies support these results where researchers emphasized the positive

impact on students, emotionally and socially, through sharing ideas and communicating with their peers (Greenhill, 2018; Lewis, 2017; Saudelli, 2012). However, this finding has not confirmed previous research, which mentioned that the challenges students face in authentic assessment tasks make them feel anxious about whether they communicate and collaborate effectively (UNSW, 2017). Students benefit from the feedback they received from their peers, teachers and experts in the same field through their communications. This confirms Singleton (2015) who mentioned that the quality of life is dependent upon relations with environment, communities, and personal relations. Students agreed that the immediate actions taken after the feedback especially from their peers has influenced the change in their perspective. It is important to note that this was in agreement with teachers' responses, that the immediate feedback is important for students' learning. As indicated by Mezirow (2003,) students attempt to reach a common understanding with others through assessing claims to rightness, sincerity, authenticity, and appropriateness.

5.2.3 Instrumental Learning

The instrumental learning occurred to focus on using multiple knowledge from different disciplines to solve complex real-life problems where students are self-directed learners who plan, design and create their own projects. This is compatible with previous studies that stated the importance of the instrumental learning where the constructivist activities are designed to develop students' problem-solving, creativity and innovation skills (Greenhill et al., 2018; Lewis, 2017; Singleton, 2015). The activities used in both graduation projects and courses were allowing students to be engaged in instrumental learning where they solve complex problems, and create innovate ideas. In the lesson plans of the graduation projects, it was mentioned that students use the acquired content knowledge from their previous learning in solving complex real-life problems and creating innovative projects through the authentic assessment tasks, which is aligned with the research of Lichfield and Dempsey (2015). The graduation projects emphasize the role of students in identifying the problems, planning and designing the projects, creating and innovating ideas. Interestingly, there is focus on students' literacy skills, especially in the robotics course and the graduation projects. Students were responsible for recording steps and to reflect on their learning using their journals and/or iPads.

As mentioned in the literature review, there are four goals that motivate students to be engaged in an instrumental learning environment: success and mastery of skills; curiosity and

understanding; originality and self-expression; relationship and involvement with others (Strong, Silver & Robinson, 1995). These goals were met by students in the experimental group as they used their previous knowledge and skills in identifying and defining the complex problems they faced in the STEAM curriculum and projects. They searched for appropriate information needed to find solutions to the problem. They were not only completing some research or open-ended investigation but also defended their solutions and claims through using different skills, such as analyzing, synthesizing, and thinking critically and creatively. This is in good agreement with the main purpose of instrumental learning that develops the knowledge of both concrete and rational spheres of the individual's understandings (Diduck & Mitchell, 2003; Mezirow, 1994). However, the control group of students cannot defend their solutions and claims through using different skills due to the lack of effective communication.

All curriculum developers and teachers strongly agreed that students can generate innovative ideas and ways of thinking in solving problems. In addition, they agreed that students complete some research or open-ended investigation into a complex topic using higher-order thinking skills (analysis, synthesis, critical thinking, and creativity) to support their solutions and claims. On the other hand, students in the experimental group stated that they were eager to plan, design and create their own projects that have innovative ideas. As mentioned in the literature review, there are three elements that promote students' creativity and take them to a higher level of thinking: integrated course, problems or projects; positive encouragement and feedback; and rewarding for completing a task (Corply, 2015; Costantino, 2018; Gross &Gross, 2016; Hunter-Doniger & Sydow, 2016; Perignat & Katz-Buonincontro, 2018).

Furthermore, all curriculum developers and teachers agreed that students can solve an ample range of problems between ill- and well-structured. These results provide confirmatory evidence of where Sternberg (2007) stated twelve strategies that are used to transform students' learning and drive the habit of creativity. These strategies lie in engaging students in open-ended tasks; encourage them to pose questions and solve them divergently; generate and communicate ideas; connect knowledge form different disciplines; challenge students; self-assess their work; provide them with ill-structured problems; lead their learning process; use different ways of authentic assessment; push them to the extent of their ability; and build self-efficacy. The curriculum developers agreed more than teachers that students are open to challenges, difficulties and risk-taking. The students of the experimental group stated that they use an extensive range of

subjects' techniques to find alternative ways of solving problems where they are open to challenges, difficulties and risk-taking. This finding confirms Schlechty (1994) who stated that engaged learners are more attracted to their tasks despite challenges or obstacles they might face. However, the control group of students stated that they feel difficulty once they find challenges and risk-taking, where they prefer the structured problems. This shows that the experimental group of students were more engaged in the learning processes. Similar results occurred with the teachers where the order of agreement came to be engineering teachers first, followed by technology and design, science, mathematics and language art teachers.

Teachers were more agreed that students use an extensive range of subjects' techniques as part of the creative process especially the use technology to provide innovative solutions. The most striking agreement occurred within engineering teachers' responses followed by technology and design, science, language art and at the end mathematics teachers. In fact, art and STEM subjects have opposite characteristics and they both make use of each other's processes (Costantino, 2018; Gross & Gross, 2016; Hunter-Doniger & Sydow, 2016; Perignat & Katz-Buonincontro, 2018; Sousa & Pilecki, 2013). As art and STEM use the convergent study of process, also they are focusing on divergent study of relationships across disciplines (Costantino, 2018; Gross & Gross, 2016; Hunter-Doniger & Sydow, 2016; Keane & Keane; 2016; Perignat & Katz-Buonincontro, 2018).

Female students stated that they were more interested to the scientific subjects when art was added to them. Previous research has emphasized that shifting from STEM to STEAM allows students to think divergently in creating different products based on their interests (Costantino, 2018; Gross & Gross, 2016; Hunter-Doniger & Sydow, 2016; Madden et al., 2013; Perignat & Katz-Buonincontro, 2018). They stated that the mechanical and electrical concepts are not boring for them as they discovered another side which is the artistic part of their projects. It makes them talk about their work and projects during their free time in order to get not only an engineering project but also to be a piece of art. This finding was in alignment with previous research who stated that adding art to STEM helps in bridging the gender gap as students are not only involved in artistic process while solving scientific problems but also their ways of viewing the scientific subjects were positively influenced (Gettings, 2017; Gidcumb, 2016). It is interesting to note that Mezirow (2003) mentioned that the learning process is to assess truth claims which require learners to discover whether their ideas are able to be implemented. This has been met where they

mentioned that they have different ideas in the beginning and they start to minimize their scope of thinking to agree altogether on one idea. It is important to bear in mind the essence behind integration of STEAM subjects where science is the hands-on, technology is the projects, engineering is the design planning, art is the creative product, and mathematics is the prominent use of modelling (Drake, 2007; France et al., 2011; Howes et al., 2013).

Furthermore, students stated that the trial and error strategy makes them know the best solution to solve their problems. This is consistent with previous studies that stated that trial and error is the best method that helps to transform students' perspectives (Greenhill et al., 2018; Lewis, 2017). On the contrary, another study result reported that although authentic assessment tasks are meaningful for students they also have challenges where there is potential for things to go wrong unpredictably and threaten students' opportunity to demonstrate their capabilities and achievements (Mueller, 2010). Students of the experimental group stated that they change their perspectives when they are challenged with complex problems. Also, they mentioned that their perspectives in viewing things changed when they test their prototypes several times and they were forced to think of another way that might work. This was in agreement with Quinn & Sinclair (2016) who mentioned the process of instrumental learning that hones students' proficiencies, knowledge, understanding of the consequences, and anticipation of the future outcomes. Students in the experimental group agreed that they felt a strong sense of responsibility, where they wanted to have innovative ideas that will serve their community. In addition, they felt the importance of changing their perspectives in order to get the best idea that is the most beneficial. It is critical to note that Singleton (2015) emphasized that students become more motivated in learning when they can transfer what they have learned to do something that has a positive impact on others or the community.

5.3 Be: Variance of students' frame of reference

The experimental and control group are equivalent to each other where the data shows no significant difference between the two groups before the treatment. In order to control variables and external factors, it was important to ensure that both groups are equivalent. A positive impact was found on students of the experimental group within the three types of learning while no significant difference was found on students of the control group. There are many factors that

affect the results: the STEAM projects and the authentic assessment are based on students' interests; existence of emancipatory, instrumental and communicative learning together; and existence of authentic tasks that allow for students' feedback and reflections. The transformation of students' learning occurred when changes in their frame of reference (habits of mind and change of points of view) takes place (Mezirow, 1997).

Results of the study show that changes in students' habits of mind, mindsets and perspective transformation are variances that occurred in students' frame of reference that led to transformative learning. The results of this study are in complete agreement with previous studies that reported the variances that occurred with students after being exposed to the emancipatory, instrumental and communicative learning (Greenhill et al., 2018; Lewis, 2017; Lindstorm, Thompson, & Schmidt-Crawford, 2017; Strange & Gibson, 2017). Students' points of view are easy to change through transforming of an individual's beliefs, values, judgments, and attitudes while their habits of mind are not easy to change because it requires students to be involved in the processes of learning (Mezirow, 1997). These processes involve: transforming frames of reference through critical reflection of assumptions within emancipatory learning; validating contend beliefs through discourse within communicative learning; and taking actions on an individual's reflective insight and critically assess it within instrumental learning (Mezirow, 1997).

The authentic assessment tasks allow students to be critical assessors where they were self-monitoring their work and correcting mistakes. This is consistent with other studies that pointed out that students are actively engaged in their learning, critically self-assessed their work, made sense of their knowledge, transfer it into new situations, and master the skills involved (Earl, 2003; Mutch, 2012). Students have a strong sense of responsibility after being engaged in the authentic assessment tasks to accomplish their projects. These results confirm Mutch (2012) who calls authentic assessment as sustainable assessment that focuses on training students to be purposeful and effective citizens and aims to develop students' attitudes and thinking, dispositions that remained after schooling where the change in their frame of reference occurred.

It has been found in similar research that students who are involved in planning and developing their integrated lessons, themes, activities, and assessments based on their interests are more likely to be engaged in discussion of global issues with a higher level of sophistications (Brown, 2002; Lepone, 2016; Saudelli, 2012). In the engineering courses, it was mentioned in the lesson plans the values and habits students acquire, such as: respect, citizenship, and team work.

Students' values and habits acquired were identified as well in the lesson plans of graduation projects where the aim is to develop the teamwork, learning and innovation, and personal and social, national and global citizenship skills.

Curriculum developers and teachers stated that the aim of the transdisciplinary STEAM curriculum and authentic assessment is that students develop their skills in order to accept working in teams, acquire learning and innovation, and personal, social, national and global citizenship competencies. These are the results of the unplanned and hidden curriculum that have been emphasized by Ornestien & Hunkins (2014). The unplanned curriculum has an important role in dealing with the socio-psychology interaction between students and teachers that lies in their feelings, attitudes and behaviours (Ornestien & Hunkins, 2014).

The curriculum developers and teachers emphasized the importance of feedback to students where it has a great impact on their work and helps in changing their perspectives. These results match the results of previous studies where transformation of students' learning occurs through the continuous feedback given to students within authentic assessment tasks such as learning logs, projects, inquiry-based and problem-based tasks (Brown et al., 1997; Race et al., 2005; Lichfield& Dempsey, 2015; Cheng, 2015; Silveira, 2013; Snyder, 2013). It is encouraging to integrate the statement of these researches to the results of the study where the teachers mentioned the importance of the immediate, earlier and constructive feedback for students that helps them to understand their weaknesses and strengths, improve their work, change their points of view, adapt their goal settings, and adjust their learning processes. Previous studies recommended that educators should emphasize the occurrence of self-reflection, critical discourse and procedural learning to promote transformative learning (Browning & Solomon, 2006; Buchman, 2012; Greenhill et al., 2018; Lawrence, 2012; Mann, 2011). Cranton (2006) pointed out that the process of examining, questioning, validating, reflecting, and revising one's perspective leads to transformative learning.

Teachers emphasized that the advantages of the transdisciplinary STEAM curriculum using authentic assessments are many and it is not only preparing students to do jobs that do not yet exist but also changes their perspective of viewing the world. This is the unplanned curriculum that lies in the humanistic approach that highly focuses on the personal and social aspects of the curriculum and instructions (Ornestien & Hunkins, 2014). This view is rooted in the progressive philosophy and the student-centred approach that focuses on the subject matter's artistic, physical,

and cultural aspects; the need for self-reflectiveness and self-actualization among learners; and overlooks the socio-psychological dynamics of the classrooms (Dewey, 1934; Taba, 1962, Schwab, 1969; Kleibard, 1989; Ornestien & Hunkins, 2014). Furthermore, it develops students' higher-order thinking skills and positively impacts their learning. This finding corroborates the study of Gettings (2017) who stated that the hidden curriculum within STEAM is the habits of mind that are known as dispositions, that include: developing crafts and knowing how to use the tools; engaging and persisting in solving problems; envisioning the consequences; expressing and representing the ideas, meanings and feelings; observing things that might not be seen ordinarily; reflecting and communicating with others; stretching their learning and exploring new concepts; and understanding the arts community.

Many teachers mentioned that the STEAM curriculum develops students' levels of creativity where they use the artistic process in the scientific subjects to solve problems and became innovative thinkers. These findings further support the idea of Drake (2007) & Jacob (1989) that integrating creative writing, visual and performing art enhances students' achievements in other subjects. Peel (2014) also emphasized that art practices help in changing students' habits of mind where artistic components are used as authentic assessment tasks that demonstrate students' understanding of science concepts, engineering and technology problems, and mathematical concepts.

5.4 Implications

5.4.1 Practical Implications

The results of the study showed a positive impact on transforming students' learning in a vocational institute in UAE due to the design of transdisciplinary STEAM curriculum using authentic assessment. The advantages of designing a transdisciplinary STEAM curriculum using authentic assessments are that students have a deeper understanding of the concept taught, are able to connect their learning to the real world, transforms the way they view the world, and allows them to learn more concepts of STEAM in less time. This confirms the findings of previous researchers who stated that a transdisciplinary curriculum requires active mental processes that allow for connection between knowledge, ideas, repetition, practice, and memorization (Gettings, 2016; Gross & Gross, 2016; Howe, 1998; Liao, 2016; Steyn, 2017; Strange & Gibson, 2017). Furthermore, the use of authentic assessment tasks allows students to learn different things based

on their interests (Elton, 2010) and also promotes students' competencies in a real-world context with many unknowns and uncertainties (Cheng, 2015).

In addition, Sousa &Pilecki (2013) found that arts help in transforming information to the long-term memory that improves students' thinking. It is important to note the impact of adding art to the STEM subjects in motivating students especially females in the scientific subjects where it reduces the stress of the heavy scientific topics. In accordance with this finding, previous studies have mentioned that adding art to STEM is not only reducing stress but also creating a pleasurable experience (Herro & Quigley, 2017; Toyoshima, Fukui & Kuda, 2011) and increase females interests toward scientific subjects (Gettings, 2017).

The use of authentic assessment tasks allows students to have several checkpoints through their learning process where they critically reflect on and self-assess their work, which makes them change their perspectives and come up with new innovative ideas. This highlights the findings of Black and William (1998) who emphasized that students who are involved in critical reflection through authentic assessments were reported to be reaching a higher level of creativity and innovation.

In addition to the communication between students to students and students to teachers and experts, there is also collaboration between students who were self-directed learners. Students were going back and forth in their way of thinking while solving problems. The complex problems that students are engaged in allow them to switch between divergent and convergent thinking which leads them to a higher level of thinking. This is in agreement with Kaufman and Beghetto (2009) who proposed the levels of creativity and indicated that the students are prepared for the higher level (pro-c) where they mastered the skills and acquired complex integrated knowledge while solving real-life problems.

Adding art to STEM was beneficial for students where they became more interested in the scientific subjects and started to think divergently of many innovative ideas. This finding is in agreement with other research findings which showed that adding art to STEM sparks the interplay between divergent and convergent thinking (Costantino, 2018; Gross & Gross, 2016; Hunter-Doniger & Sydow, 2016; Perignat & Katz-Buonincontro, 2018; Yakman, 2007). This is in addition to planning, designing, and creating their own projects that show the development of creativity and innovation skills. These findings confirm that arts play an important role in developing learners' cognitive, emotional and psychomotor pathways in the brain (Sousa & Pilecki, 2013).

These pathways are enhanced through the use of emancipatory, communicative and instrumental learning that lead to transformative learning (Liao, 2016; Peel, 2014).

5.4.2 Professional Implications

The results show that the transdisciplinary STEAM curriculum is constructively aligned to the authentic assessments using Drake's KDB model (2004) where there was clear alignment between what students need to know; what will they do; and what are they going to be. This model emphasizes the use of backward design (Drake & Burns, 2007). The authentic assessments used are "assessment as learning" where there are several checkpoints of feedback, self-assessment, and critical reflection, which reflect the emancipatory learning practices. The importance of critical reflection has been highlighted in a previous study as it provided learners with opportunities to critique assumptions and worldviews, examine them, and accept or reject them (Fook & Sidu, 2013). Teachers started to shift their focus from teaching to learning, where authentic assessment design forced them to create several checkpoints for students' self-evaluation and reflection. As reported by many researchers, the authentic assessment tasks inspired teachers to focus more on the learning (Black & William, 1998; Keane & Keane, 2016; Sousa & Pilecki, 2013).

Regarding the challenges in designing a transdisciplinary STEAM curriculum using authentic assessments, the curriculum developers face more challenges than teachers. This is because of the coverage of the curriculum materials within each subject. This is similar to what was mentioned by Beane (1995) who emphasized the use of the higher level of integrated curriculum that might cause a loss to separate subjects. However, Beane's response was in agreement with Dewey, Whitehead and Gardner who believe in teaching a lesser amount of meaningful information with more depth, based on students' interests (Lepone, 2016). It was stated by curriculum developers that designing a STEAM curriculum with a higher level of integration requires proper alignment between curriculum, assessment, instructions, and the country's vision. In addition, they all agreed that it is time consuming and requires highly effective collaboration and communication between departments. It has been stated by Drake and Burns (2004) that the integrated curriculum is challenging as it requires high collaboration between teachers. On the contrary, the results of Leopone's study (2016) emphasized that teachers' collaboration has been improved using Drake's model. Furthermore, the instructional activities are not easy to design in a way that requires students to critically reflect on their learning several times during the time required to complete the task.

In addition, teachers have to look at the curriculum vertically and horizontally in order to find areas of integration between disciplines and suitable to the grade level taught. This result supports Drake and Burns (2010) ways of planning using the KDB model which requires effective collaboration between departments in order to design integrated units; read across curriculum vertically and horizontally; choose an appropriate theme; brainstorm activities; create rich assessments; create guided questions; then design instructional activities. This is in alignment with a study by Leopone (2016) who stated that collaboration between teachers has improved and new strategies have been shared among them; there were no similar results stated in the current study. However, teachers and curriculum developers mentioned how time consuming it had been to design the curriculum using the KDB model.

On the contrary, teachers mentioned that the design of the graduation projects were smoother in the process of the STEAM curriculum. This is due to the way of planning where teachers guide students through several steps in planning their projects as they have to write ten questions individually; then students work together to find commonalities between the questions; then eliminate the questions posed and identify a theme; and finally, they plan the unit, assessment tools, and activities with the teachers. These findings provide further evidence of Beane (1995) who suggested ways of planning a transdisciplinary curriculum that should be based on students' interests, and their involvement in the planning process, as this makes learning more effective when they investigate the questions they have posed.

In addition, Mutch (2012) emphasized the roles of teachers and students in co-constructing and designing the authentic assessment tasks and building in checkpoints to monitor progress and share assessment information. This finding also confirms Black & William's (1998) results where the design of a transdisciplinary curriculum using authentic assessment inspires teachers to shift the focus from teaching to learning. It is highly recommended that teachers should guide students and leave their learning outcomes open-ended, to accommodate and expect from them the unexpected unique products that encourage their creativity (Cheng, 2015; Earl, 2013). It is interesting and important to note that the teachers' perceptions, knowledge and overall confidence in teaching STEAM increased. This is in good agreement with a study of Nadelson et al. (2013) who stated that teachers' perceptions, practices and confidence increased; however, there was a challenge in hiring experienced teachers in teaching STEM. This current study has not confirmed previous research that the STEM contents focus on science or mathematics subjects and seldom

on engineering and technology (Herro & Quigley, 2017). In contrast, the contents were real-life problems that have a complex integration where the boundaries of subjects were blurred.

Curriculum team responses regarding the advantages were in good agreement with other researchers who stated that students' abilities to gain information has increased, where they learn more concepts in less time and in more depth which may lead them to transformative learning due to the frequent critical reflection during the learning process (Drake & Reid, 2010; Jacobs, 1989; Leopone, 2016). Furthermore, Dowsen (2003) mentioned that the teachers' focus is to produce higher test scores, and therefore teachers prefer to stick with what they know and they distrust the use of an integrated curriculum. Also, Miller (2017) mentioned the tension formed between teaching a transdisciplinary curriculum and preparing students to achieve higher grades in standardized assessments that hinders transforming students' learning. On the contrary, the current study results emphasize that a transdisciplinary STEAM curriculum using authentic assessments can help in preparing students to achieve higher grades in standardized assessments like TIMSS. This is supported by a study of Hunter-Doniger and Sydow (2016) who mentioned that exposing students to real-life problems that requires integrated STEAM subjects had a positive impact on increasing students' results in standardized assessments.

The interdisciplinary approach that requires less integration between subjects has been criticized by Beane (1991), and the focus changed to the transdisciplinary curriculum where the probability of separate subjects does not exist. It is important to note that the graduation projects were more strongly integrated than the courses that are blurred between disciplines boundaries. However, Beane has been criticized about teaching an integrated curriculum where teachers have no time to finish their curriculum. It has been proved from Beane, Dewey, Gardner, and Whitehead that teaching a lesser amount of content but in more depth, is more beneficial in getting students to reach higher-order thinking (Leoplone, 2016). The design of authentic assessments used in the current study has several authentic tasks such as: collaborative activities, assignments, projects, problems, and journals, which confirms Lichfield and Dempsey (2015) who shifted the focus from formative traditional assessment to authentic assessment that is full of tasks and allows students to self-assess, reflect and get feedback on their work. The authentic assessment is a kind of assessment as learning where the main purpose is sustainability (Almqvist et al., 2017) and students are engaged as critical assessors (Earl, 2003). This scenario has been reflected clearly in this study where the planning shows the several tasks used for authentic assessment and the

students' roles in reflecting, self-assessing, and getting feedback on their work. On the other hand, integrating art into STEM allows information to be transferred to the long-term memory (Sousa & Pilecki, 2013); this was reflected in curriculum developers' and teachers' responses where they stated that the transdisciplinary curriculum allows for learning both breadth and depth of knowledge.

Furthermore, Drake and Reid (2010) emphasized that the integrated curriculum reduces the stress of teaching multiple expectations. Regarding the curriculum developers' and teachers' practices and perceptions of designing the transdisciplinary curriculum using authentic assessments, it was stated that the engineering teachers were extremely positive; science and technology and design were positive; English teachers were changing between low and medium agreement; while mathematics teachers remain the lowest in agreement. These results offer crucial evidence of Leopone's (2016) study who stated that some teachers found difficulty in teaching specific mathematics concepts; however, the concepts taught have been covered by bearing big ideas.

The majority of participants are teachers who have bachelor and master degrees, most of them in science and engineering. On the other hand, a minority of participants have a professional or doctorate degree, many of them from an engineering background. Regarding the gender difference, the total number of female teachers is higher than male teachers. The majority of participants' experience is between 11 to 15 years. The majority of participants were teachers who have teaching loads while the minority are curriculum developers who do not have any teaching loads. As a result, the data will be focusing on the teaching and non-teaching positions of participants who are involved in designing and planning a transdisciplinary STEAM curriculum using authentic assessments. It is interesting to note that engineering teachers had the highest agreement in responses about critical thinking skills within emancipatory learning, followed by English language teachers, science teachers, mathematics teachers and technology and design teachers. Similar results of agreement emerged between teachers about the independent learning skills within emancipatory learning, where engineering teachers had highest agreement followed by technology and design, language art, science and mathematics teachers. It is interesting to note that engineering teachers' agreement stayed the highest across all skills within communicative learning while technology and design were the second highest agreement with communication and collaboration skills and the third with self-direction skills. On the contrary, science teachers'

responses were the second highest agreement with self-direction skills, third with communication skills, and fourth with collaboration skills. Language art teachers' responses were third with collaboration skills and the lowest in both communication and self-direction skills. The minority agreement shows with the mathematics teachers' responses who were the lowest in collaboration skills and the fourth with communication and self-direction skills.

5.5 Conclusion

This study aimed to investigate the impact of designing a transdisciplinary STEAM curriculum using authentic assessment on transforming students' learning in a vocational institute in the UAE. The questions of the study have been addressed where the results showed that the use of authentic assessment tasks within the transdisciplinary STEAM curriculum has a positive impact on students' work and changes their perspectives in viewing the world. The results of this study emphasize Drake & Burns (2004) who stated that the primary assessment for the transdisciplinary curriculum is the authentic assessment. The design of the transdisciplinary STEAM curriculum uses the backward design where the curriculum was constructively aligning the desired outcomes, assessments, and learning plans. This helped curriculum developers and teachers to plan the authentic assessment tasks easily in less time. The authentic assessment is designed based on the backward design that involves clear criteria and performance standards, which was shared with the students. Constructivism was used as the backbone of designing the transdisciplinary STEAM curriculum using authentic assessment that cut across the three types of learning (emancipatory, communicative and instrumental). It is interesting and important to note that it was highlighted that constructivism is the backbone of designing integrated units that are aligned to the outcomes of industry expectations (ElSayary, Forawi & Mansour, 2015) and to the assessments that are rich in the contexts of performance in the real world (Wiggins, 1990).
Teachers and curriculum developers have the greatest role in facilitating learning for students and in designing the curriculum and tasks based on their interests. The treatment given to the experimental group was the link between the STEAM curriculum and authentic assessment tasks that cut across three types of learning: emancipatory, communicative, and instrumental learning.

The results showed a significant difference between the pretest and posttest where the combination of the three types of learning helped in transforming students' learning. The results

of the study emphasize the importance of exposing students to the three types of learning while solving complex real-world problems collaboratively and self-assessing their learning on transforming students' frames of reference. Strong correlations were found between emancipatory learning, communicative learning, instrumental learning, and students' results. This proves that the design of the transdisciplinary STEAM curriculum using authentic assessment tasks cut across the three types of learning that were highly impacting students' learning. Previous studies emphasized the important use of the emancipatory, communicative and instrumental learning that will lead to students' transformation of their perspectives (Cranton; 2002; Greenhill et al., 2018; Lewis, 2017). However, the strongest correlation was found between the emancipatory learning and instrumental learning where the students' reflection, feedback, awareness of their weaknesses and strengths affected their ways of solving problems, accepting challenges, and risk-taking.

The results of the study emphasized that students who build relationships with their peers, community and world; critically reflect on their learning; and are actively engaged in solving complex problems are more likely to transform their perspectives, change their behaviours and become engaged in sustainable community practices. There were no significant differences between males and females of the experimental group. This is because students' learning and choices were based on their interests as stated by previous researches (Gettings, 2017; Gidcumb, 2016; UNESCO, 2017). The graduation projects were fully based on students' interests that reflect Beane's (1991) approach while the courses were designed using Drake's model (2004). The courses rely on teachers and curriculum expectations which is considered to be Drake's approach, while the graduation projects rely mainly on students' interests where they lead their own learning starting from the design of the project. The graduation project and the courses were both highly integrated in a very complex way, however, the graduation project is considered to be more complex. They both follow the third way of Dugger and Fellow (2011) about integration where all subjects were intertwined below one main subject.

It was found that the teaching for transformation is challenging for teachers when they have to bring students from what they currently know to the learning goals of the courses. Students become aware of their strengths and weaknesses, self-assess their work, give feedback and reflect on their learning; transfer what they have learned into new situations; communicate and collaborate effectively; and are able to plan, think critically and creatively in solving complex real-world problems. These values have been found in previous studies, which confirmed that the use of

authentic assessment with a transdisciplinary curriculum cut across three types of learning: emancipatory, communicative and instrumental learning that allow students to develop their skills within each type of learning (Naidoo & Kirch, 2016; Turner, 2015; Merilainen & Piispanen, 2013; Vasequez, Sneider & Comer, 2013). Students felt satisfied by their learning and the change occurred in their perspectives and mindset. They feel the value of the transformation and how they will benefit their community. This was evidenced in designing the transdisciplinary STEAM graduation projects in order to address social and global issues that lead to students' transformational learning. The reflection and feedback within emancipatory learning have a critical role with students, that moves them to the communicative learning where their collaboration and communication leads to the instrumental learning in order to solve complex real-world problems.

The transdisciplinary STEAM curriculum requires students to go through different types of learning that force them to use a wide variety of habits of mind that lead to transformative learning. The arrangement of authentic assessment tasks where there are several checkpoints of continuous feedback and reflection helps in changing students' perspectives. The significant role of authentic assessments is to provide students with opportunities for critical reflection which is essential within the process of learning real-life situations that lie in intellectual, personal, and dialogue reflection. This study provides additional support to other studies that stated that the feedback given to students not only influences their lives and careers but also changes their perspectives and leads them to transformation in their learning (Litchfield & Dempsey, 2015; Cheng, 2015; Silveria, 2013; Snyder, 2013). All participants of the study (students, teachers and curriculum developers) emphasized the importance of students' feedback; however, teachers added that students need to get the feedback immediately as this will be more beneficial for them, in addition to their teaching practice of modifying instructions when needed. In addition, students' feedback and reflection during authentic assessment tasks help in developing communication, collaboration, critical thinking, creativity and innovation, and self-direction skills that have a great impact on students' learning.

Teachers and curriculum developers understand their students and their capabilities and the authentic tasks, challenges, and problems were tailored to not only challenge students but also to examine their perspectives, develop their skills, acquire new knowledge, and innovate new ideas that benefit their communities. It is significant that teachers understand students' backgrounds,

beliefs, and knowledge in order to create an effective critical event; examine their perspectives by providing them with conflicting points of view; challenge their beliefs; and set up a failure-driven approach that motivates them in solving problems.

Teachers believe that they have several roles during authentic assessment processes and the importance of reflection, self-assessment, and feedback during this process. Teachers were acting as mentors who provide students with feedback; guides who gather diagnostic information to lead students through the work at hand; accountants who maintain records of students' progress and achievement; reporters to report about students' progress and achievement to parents, students, and school; and programme directors to make adjustments and revisions to instructional practices. Furthermore, students' roles were as critical assessors of their work and their peers' work. The use of authentic assessment tasks helps in transforming students' learning due to being engaged in high impact practices. There is perfect agreement about this implication with Landy (2015) who stated that the use of authentic assessment tasks within pedagogies and practices requires a complex integration of knowledge (transdisciplinary) where it has a great impact on transforming students' learning.

The use of authentic assessment tasks allowed students to have several checkpoints that helped them to reflect, receive feedback and self-assess their work. It is important to note that assessment occurs as part of learning over an extended period of time when students are engaged in authentic and complex tasks in order to examine their beliefs and assumptions. In addition, teachers and curriculum developers emphasized that authentic assessments provide students with feedback that allows them to critically reflect on their learning and should vary authentically. It has been mentioned in this study that the transformative learning theory is very effective not only with adults but also with children of a young age. A study of Singleton (2015) emphasized that the transformative learning theory is very effective when it starts with young children as it makes them self-regulated learners; having curiosity that motivates them to be engaged in learning; and reflect critically on their learning.

Adding art to STEM subjects helped in transforming students' learning due to the integration of artistic concepts with the scientific concepts where students have benefited from the inductive and deductive approaches of learning. These results reported that adding the art to the scientific subjects allows students to be engaged in different types of learning that leads to transforming their frames of reference. Furthermore, adding art to STEM was beneficial for

students when it attracted them to the complex scientific subjects in order to get artistic products and helped them to switch between the divergent and convergent thinking in order to get innovative ideas. It has been mentioned that art and STEM make use of each other's processes, as the interplay between art knowledge and STEM knowledge is highlighted when both inform investigations and putting forward propositions. In other words, art plays an important role in developing learners' cognitive, emotional, and psychomotor pathways which enhances the emancipatory, communicative and instrumental learning that leads to a transformation of their frames of reference.

The STEAM allowed students to experience professions and careers based on their interests which led them to a certain degree of creativity. Kaufman and Beghetto (2009) mentioned a new category of creativity that is called little-c, and pro-c where it is considered to be between the mini-c and Big-c. It was mentioned that the mini-c is the starting point of transformation where a change in learners' perspectives and habits occurs to shift them to the next level of creativity (Kaufman & Beghetto, 2009). This is aligned with the Vygotskian conception of cognitive and creative development which argues that all learners have the potential and basics of being creative (Moran & John-Steiner, 2003). The little-c is the stage where students were engaged in emancipatory, communicative and instrumental learning in which they will be encouraged to attain the next level of creativity. As a result, the students in this study were in the second level of creativity (little-c) from where they were about to jump to the third level after pursuing their interests.

5.6 Recommendations

It is highly recommended that students' attitudes towards the STEAM career choices are measured in order to bridge the gap that occurs in pursuing more humanities and business fields than STEAM fields. For further studies, it is recommended to investigate the impact of using authentic assessment tasks within a STEAM curriculum in raising students' results in standardized assessments such as TIMSS and PISA. Miller (2017) mentioned the challenges that educators face in transforming students' learning: standardized assessments, lack of teachers' preparation, and limited resources. That was not the situation with this study where there was no lack in teachers' preparations and no limited resources, however, the standardized assessments remained a

challenge. Teachers' professional development is important to consider: the weaknesses and strengths of their practices where more focus should be taken to train teachers on how to guide students and leave their learning outcomes open-ended, to accommodate, and expect from their students the unexpected unique products that encourage their creativity. For further studies, it is recommended to repeat the study with other schools and not to be limited to vocational institutes. Students' journals, logs, and reflections need to be analyzed to ensure the quality of their reflection and its impact on their learning. It will be beneficial to measure the impact of transformative learning on students' results of the Cognitive Ability Test (CAT4) that consists of four sections, verbal, non-verbal, quantitative and spatial reasoning, which are compatible with STEAM reasoning skills. Further investigations are needed to explore the different types of reflection and analyze the quality of it for teachers as well as students. It is highly recommended to investigate the correlation between subjects and its impact on transforming students' learning.

5.7 Limitations

This study aimed to use the multiphase mixed method that not only focuses on the breadth of the study but also focuses on the depth. This caused a lot of effort, time and resources to accomplish the study. This study took place in a vocational school and the generalization of this study is subject to certain limitation. In addition, the sample selected of the experimental group was limited due to the limitation of accessing more places that might apply the treatment. Furthermore, the data collection of this study is self-reported and so might include bias and affect validity. One of the main limitations in this study is that students' journals were not analyzed which could have added a deeper understanding of the transformation that occurred. The most significant limitation lies in the fact that the skills acquired within each type of learning are intertwined together in a very complex way which caused a heavy reliance on the researcher to use multiple data to validate the results. Finally, the sequential method used within each phase requires that one method follows the other and the challenge was to try to find the point of interface in which the researcher needed to investigate which results from the first part would become the focus for the second part.

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Appendices

Appendix A: Consent Form

الجامعة البريطانية في دبي
The British University in Dubai
www.buid.ac.ae

19 February 2017

To Whom It May Concern

This is to certify that **Ms Areej ElSayary** with ID number **2015121056** is a registered part-time student on the **Doctor of Education** programme in The British University in Dubai since **September 2015**.

Ms ElSayary is currently working on her research titled "**Impact of Designing Transdisciplinary STEAM Curriculum and Authentic Assessment on Transforming Student Learning**". She is required to collection data through:

1. Document Analysis of Lesson & Curriculum Planning
2. Curriculum Team's Questionnaire
3. Pre- and Post-Survey for Students
4. Focus Group Discussion

Further support provided to her in this regard will be highly appreciated.

This letter is issued on Ms ElSayary's request.

Yours sincerely,

الجامعة البريطانية في دبي
الإدارة الطلابية
Student Administration
The British University in Dubai

Amer Alaya
Head of Student Administration

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Appendix B: Document Analysis

Transdisciplinary Lesson Plan Analysis Tool

Name of the Lesson:	**Duration of the Lesson:**
Grade Level:	**Course Name:**

Essential questions before reviewing the book (Yes or No)

Does the lesson plan Includes the backward design components:

Desired Outcomes

- Enduring Understanding
- Essential Question
- Content / Knowledge
- Skills / Objectives
- Competencies

Assessment Criteria

- Type of assessment
- Method of assessment

Learning Plan

- Activities / Challenge
- Resources / Materials
- Differentiated instructions
- Teachers' Reflection
- Students' Reflection

If the answer to any of the above three questions is "no" do not continue the evaluation.

Knowledge	**Yes**	**Somewhat**	**No**
What is most important for students to KNOW?			
What is the level of knowledge used in planning? a. Fact b. Topic c. Concepts d. Enduring Understanding e. Principles and Theories			
Is the identified theme age-appropriate and relevant to students?			
According to Dugger and Fellow models, what kind of integration is the course?			
Assessments Design			
Does the assessment: a. Reflect the Know, Do, and Be bridge? b. Provide a way to celebrate learning? c. Clearly identify what students are to do (e.g: rubrics are shared in advance)?			

d. Require an external audience to witness assess the performance/demonstration?			
Is the pace of assessments broadly even, allowing assessments to rest and plan ahead?			
Guided Questions			
Do questions created to: a. Provide a framework for the unit? Or guide students' learning? b. Include topic and essential questions? c. Encourage inquiry and multiple answers? d. Encompass a substantial part of the unit? e. Connect to student interests?			
Comments:			

Do		**newhat**	**No**
What is most important for students to do?			
What are the level of skills identified in planning: a. Lower-order skills: require students to regurgitate existing knowledge: list, recall, identify, describe, summarize, recognize, explain, illustrate b. Discipline specific skills: require students to do something active with the content: Construct and Interpret, Design, Compare, Perform, Create. c. Interdisciplinary Skills: require complex performances; students are producers of knowledge: Information management, Research, Critical thinking, Communication, Problem solving			
Do the activities engage students in instrumental learning (inquiry/problem-solving)?			
Is there enough variety and choice in activities to address diverse learning needs?			
Does each activity connect to a guiding question?			
Do activities aligned with the culminating assessment and KDB?			
Do activities allow for communicative learning?			
Do performance-based assessments include meaningful and relevant indicators of quality performance?			
What kind of assessments used to assess students			

integrated knowledge and skills? • self-assessment, • peer assessment, • performance, • rubrics, • journals, • portfolios, • observations • checklists			
Comments:			
Be	**Yes**	**Somewhat**	**No**
What kind of person do we want students to BE? a. "Habits of mind" such as respect, teamwork, citizenship. b. What values can students acquire?			
Do students demonstrate: a. Self-direction b. Reflection c. Goal setting d. Cooperation e. Self-evaluation f. Being inviting to others g. Making good life choices			
Does the plan include time for students' post conference (discussing feedback and setting plans to improve)?			
Comments:			

Appendix C: Curriculum Team's Questionnaire

Consent Form for Curriculum Team

Dear Sir/Ms.,

I am a graduate student in the British University in Dubai BUID. I am doing a research about "*Impact of Designing Transdisciplinary STEAM Curriculum and Authentic Assessment on Transforming Student Learning*". I am conducting a research study to investigate the impact of designing and planning transdisciplinary curriculum using authentic assessment to transform students' learning. In addition, the extent of the change occurred in students' learning will be investigated. Grade 12 students and curriculum team will know that they are being asked for their input about their perceptions and practices of the acceptance in participating in this study.

The participation in this questionnaire will involve answering questions relating to your demographic background and questions related to your perceptions and practices in designing and planning transdisciplinary curriculum, authentic assessment, and instructional activities.

Your participation in this study is voluntary. If you choose not to participate or withdraw from the study at any time, there will be no penalty. The information collected from this questionnaire is anonymous and confidential.

Thank you for being part of this research. I truly appreciate your time and effort in answering the questionnaire for my research. If you have any questions concerning this research study, please contact me on the following email: areej.elsayary@gmail.com.

Sincerely,

Areej ElSayary

Areej.elsayary@gmail.com

Curriculum Team's Questionnaire

Purpose of the Questionnaire

The purpose of this questionnaire is to investigate the impact of designing transdisciplinary curriculum using authentic assessment in transforming students' learning.

How to Answer each Question

The questionnaire is categorized by sections: Section 1 involves demographic information; Section 2 is Likert-scale items that involves emancipatory, instrumental, and communicative learning; and Section 3 involves three open-ended questions.

The questionnaire will take 10-15 minutes. The information collected from this questionnaire is anonymous and confidential. Thank you for being part of this research. Your cooperation is highly appreciated.

Section 1:

1. What is the highest level of education you have completed?

   Bachelor's degree Master's degree Professional degree Doctorate degree
2. What is your gender?

   Male Female
3. What is your position?

   Curriculum Developer Coordinator Lead teacher Teacher
4. How many years of experience do you have?

   0 – 5 6 – 10 11 – 15 16 – 20
5. What is your specialization?

   Science Technology Engineering Language Art Mathematics
6. How many PDP did you attend in the last 2 years?

   0 – 5 6 – 10

Section 2:

Please use the key below to indicate the extent of your agreement or disagreement with each statement.

(5) SA: Strongly agree (4) A: Agree (3) N: Neutral (2) D: Disagree

(1) DA: Strongly disagree

Curriculum & Assessment Design		5	4	3	2	1
To what extent do you agree with the following while designing and planning transdisciplinary curriculum with authentic assessment:		SA	A	N	D	SD
1	Integration between disciplines allows for more concepts that can be taught in less time and in higher levels					
2	Shift from STEM to STEAM allow students to think divergently where each create different product based on their points of views					
3	Design of transdisciplinary curriculum relates closely to career goals and practice					
4	The course requirements, instructional activities, and assessments are designed to a certain degree that allow students to experience the fidelity of authentic tasks.					
5	The design of transdisciplinary curriculum using authentic assessment afford students' engagement and active learning.					
6	The design of transdisciplinary curriculum using authentic assessment provide challenge, interest, and motivation to learn.					
7	Transdisciplinary curriculum focuses on different ways of looking at the world					
8	The authentic assessment is designed to give students feedback in a more motivational form.					
9	Authentic assessments take time at both creation and grading stages.					
10	Students do not learn the same way; accordingly, they are not assessed the same way.					
11	Each activity in authentic assessment includes detailed instructions and guidelines for students to ensure the completion of the requirements.					
12	Authentic assessment aims to connect between contents and apply new knowledge into meaningful and relevant tasks.					
13	An indicator of students' attainment to their knowledge, skills, and attitudes is completing relevant activities and investigations.					
Emancipatory Learning (Reflective Learning)		5	4	3	2	1

To what extent do you agree in integrating the following skills while planning instructional activities:		SA	A	N	D	SD
Critical Thinking						
14	Students gather, evaluate, and synthesis information from different sources.					
15	Logically connect between ideas, contents, concepts, and area of learnings.					
16	Students use integrated knowledge to solve problems logically.					
17	Students reflect on their own beliefs, values and points of views from local and global perspectives.					
Independent Learning						
18	Students use extensive range of resources and technologies independently.					
19	Students set clear and challenging targets that consistently be achieved and adapted in the light of experience.					
20	Students reflect and evaluate their own learning and outcomes of that learning.					
Instrumental Learning		5	4	3	2	1
To what extent do you agree in integrating the following skills while planning instructional activities:		SA	A	N	D	SD
Creativity and Innovation						
21	Students generate innovative ideas and ways of thinking in solving problems.					
22	Students use an extensive range of subjects' techniques as part of the creative process.					
23	Students are open to challenges, difficulties and risk-taking					
Problem Solving						
24	Students complete a research or open-ended investigation into a complex topic using higher-order thinking skills (analysis, synthesis, critical thinking, and creativity) to support their solutions and claims.					
25	Students use technology to provide innovative solutions for problems that fit to the purpose.					
26	Students solve an ample range of problems between well- and ill-structured.					
Communicative Learning		5	4	3	2	1
To what extent do you agree in integrating the following skills while planning instructional activities:		SA	A	N	D	SD

Communication						
27	Students communicate using an extensive range of methods: verbal, written, visual, and/or non-verbal.					
28	Students organize the content of their thoughts and communication into a logical and coherent whole					
29	Students use a wide range of modern technologies effectively and confidently as a means of communication					
Collaboration						
30	Students work productively with others from a wide range of social and cultural backgrounds					
31	Students argue a point of view respectfully when challenging the differing views of an individual or the team					
32	Students work with others to guide, counsel and motivate team members to achieve team goals					
Self-direction						
33	Students initiate a range of simple and complex activities and tasks which advance their knowledge, understanding and skills					
34	Students plan, define and work towards goals and targets without the need to be pushed, driven or managed by others					
35	Students recognize opportunities for self-advancement and opportunities that will benefit others					
36	Students take responsibility and make decisions to resolve issues					

Section 3:

1. What is the impact of the feedback given to students and what is the duration between each feedback?
2. What are the challenges in designing lesson plans using transdisciplinary and authentic assessment?
3. What are the advantages of designing transdisciplinary curriculum with authentic assessments?

Appendix D: Pre- and Post-Survey for Students

Consent Form for Students' Survey & Focus Group Discussion

Dear Sir/Ms.,

I am a graduate student in the British University in Dubai BUID and doing a research about "*Impact of Designing Transdisciplinary STEAM Curriculum and Authentic Assessment on Transforming Student Learning*". I am conducting a research study to investigate the extent of the change occurred in students' learning. As grade 12 students, you are kindly asked for your input about your perceptions and practices of the acceptance in participating in this study.

This survey will be conducted twice: in the beginning of this term and at the end of this term. The participation in this survey will involve answering questions relating to your demographic background and questions related to your perceptions and practices in your emancipatory, instrumental, and communicative learning. The focus group discussion will be conducted after the post-survey that aims to investigate in depth the students' perceptions in reflecting on their learning experiences.

Your participation in this study is voluntary. If you choose not to participate or withdraw from the study at any time, there will be no penalty. The information collected from this survey is anonymous and confidential.

Thank you for being part of this research. I truly appreciate your time and effort in answering the questionnaire for my research. If you have any questions concerning this research study, please contact me on the following email: areej.elsayary@gmail.com.

Sincerely,

Areej ElSayary

Areej.elsayary@gmail.com

Pre- & Post-Students' Survey

Purpose of the Survey

The purpose of this survey is to investigate the extent of the change occurred in students' learning. Your responses will be taken twice; in the beginning and end of term.

How to Answer each Question

The survey is categorized by sections: Section 1 involves demographic information; and Section 2 is Likert-scale items that involves emancipatory, instrumental, and communicative learning.

The survey will take 10-15 minutes. The information collected from this survey is anonymous and confidential. Thank you for being part of this research. Your cooperation is highly appreciated.

Section 1

7. What is your gender?
    - Male
    - Female
8. What is your age?
    - Below 16
    - 16 – 17
    - Above 17
9. What is your proficiency level in Science courses?
    - Weak
    - Intermediate
    - Advanced
10. What is your proficiency level in using technology?
    - Weak
    - Intermediate
    - Advanced
11. What is your proficiency level in using engineering courses?

- Weak
- Intermediate
- Advanced

12. What is your proficiency level in English Language Art?
    - Weak
    - Intermediate
    - Advanced
13. What is your proficiency level in Mathematics?
    - Weak
    - Intermediate
    - Advanced

Section 2

Please use the key below to indicate the extent of your agreement or disagreement with each statement.

(5) SA: Strongly agree (4) A: Agree (3) N: Neutral (2) D: Disagree (1) DA: Strongly disagree

Emancipatory Learning (Reflective Learning)		5	4	3	2	1
To what extent do you do the following while learning:		SA	A	N	D	SD
1	I recognize problems I might face to accomplish my goals					
2	I define constraints of the problems					
3	I set clear and challenging targets to be achieved					
4	My previous experience affect me while thinking of the problems.					
5	I reflect on my own beliefs, values and points of views from local and global perspectives.					
6	I reflect and evaluate my own learning and outcomes of that learning.					
Instrumental Learning		5	4	3	2	1
To what extent do you do the following while learning:		SA	A	N	D	SD
7	I use an extensive range of subjects' techniques to find alternative ways of solving problems					
8	I am open to challenges, difficulties and risk-taking					
9	I use my previous knowledge and skills in identifying and defining a complex problem					
10	I articulate knowledge needed to find solutions for the problem.					
11	I complete a research or open-ended investigation of a complex topic					
12	I defend my solutions and claims through using different skills (analyzing, synthesizing, thinking critically and creatively).					

Communicative Learning		5	4	3	2	1
To what extent do you do the following while learning:		SA	A	N	D	SD
13	I communicate information accurately, clearly, confidently and as intended.					
14	I use a wide range of modern technologies effectively and confidently as a means of communication					
15	I work productively with others from a wide range of social and cultural backgrounds					
16	I plan, define and work towards goals and targets independently					
17	I argue a point of view respectfully when challenging the differing views of an individual or the team					
18	I work with my peers to find alternative solutions of the problems					
19	I connect between ideas with my peers to find the most suitable way of solving problem					

Appendix E: Students' Focus Group Discussions

Focus Group Questions

This focus group is part of research that included the survey you took. The research is about the experiences of learners. We believe that important things happen when you learn new things and how your perspective has changed. Only with your help we can learn more about this. The focus group should only take half an hour to complete, and your responses will be anonymous. Thank you in advance for being part of this project; your cooperation is greatly appreciated. The focus group questions are designed to gather further information about the topics covered in the original survey, so some of them may sound familiar to you.

Thinking back over your learning practices in this course, have you experienced a time when you realized that your values, beliefs or expectations had changed?

Instrumental

1. What is the cause of the change? (*Content*)
2. How did you first realize this change? (*Process*)

    - While it was happening
    - Mid-change
    - Once it had entirely happened

3. Why is this change important to you? (*Premise*)

Communicative

4. What do others say about this change? (*Content*)
5. How did this change been socially influenced? (*Process*)
6. Why should you believe in this change? (*Premise*)

Emancipatory

7. What are your assumptions of the change? (*Content*)
8. How did you obtain this change (or know that your assumptions are valid)? (*Process*)
9. Why should you revise/ not revise your perspective? (*Premise*)

Appendix F: Students' Results of Pilot Study

Item Statistics			
SUMMARY	**Mean**	**Std. Deviation**	**N**
I recognize problems I might face to accomplish my goals	2.00	.711	84
I define constraints of the problems	2.31	.776	84
I set clear and challenging targets to be achieved	2.24	.887	84
My previous experience affect me while thinking of the problems.	2.11	1.018	84
I reflect on my own beliefs, values and points of views from local and global perspectives.	1.95	.890	84
I reflect and evaluate my own learning and outcomes of that learning.	2.12	.870	84
I use an extensive range of subjects' techniques to find alternative ways of solving problems	2.43	1.021	84
I am open to challenges, difficulties and risk-taking	2.32	1.043	84
I use my previous knowledge and skills in identifying and defining a complex problem	2.02	.931	84
I articulate knowledge needed to find solutions for the problem.	2.15	.925	84
I complete a research or open-ended investigation of a complex topic	2.40	1.007	84
I defend my solutions and claims through using different skills (analyzing, synthesizing, thinking critically and creativity	2.31	1.029	84
I recognize problems I might face to accomplish my goals	1.86	.823	84
I define constraints of the problems	2.20	.818	84
I set clear and challenging targets to be achieved	2.07	.916	84
My previous experience affect me while thinking of the problems.	2.10	1.025	84
I reflect on my own beliefs, values and points of views from local and global perspectives.	1.89	.878	84
I reflect and evaluate my own learning and outcomes of that learning.	2.15	.912	84

Reliability Statistics		
Cronbach's Alpha	**Cronbach's Alpha Based on Standardized Items**	**N of Items**
.918	.920	18

Appendix G: Curriculum Team's Results of Pilot Study

SUMMARY	N	Mean	Variance	SD
Integration between disciplines allows for more concepts that can be taught in less time and in higher levels	32	1.00	0.00	0.00
Shift from STEM to STEAM allow students to think divergently where each create different product based on their points of views	32	1.06	0.06	0.25
Design of transdisciplinary curriculum relates closely to career goals and practice	32	2.00	0.00	0.00
The course requirements, instructional activities, and assessments are designed to a certain degree that allow students to experience the fidelity of authentic tasks.	32	2.00	0.00	0.00
The design of transdisciplinary curriculum using authentic assessment afford students' engagement and active learning.	32	1.06	0.06	0.25
The design of transdisciplinary curriculum using authentic assessment provide challenge, interest, and motivation to learn.	32	1.00	0.00	0.00
Transdisciplinary curriculum focuses on different ways of looking at the world	32	2.00	0.00	0.00
The authentic assessment is designed to give students feedback in a more motivational form.	32	1.00	0.00	0.00
Authentic assessments take time at both creation and grading stages.	32	1.03	0.03	0.18
Students do not learn the same way; accordingly, they are not assessed the same way.	32	1.03	0.03	0.18
Each activity in authentic assessment includes detailed instructions and guidelines for students to ensure the completion of the requirements.	32	1.03	0.03	0.18
Authentic assessment aims to connect between contents and apply new knowledge into meaningful and relevant tasks.	32	2.00	0.00	0.00
An indicator of students' attainment to their knowledge, skills, and attitudes is completing relevant activities and investigations.	32	1.00	0.00	0.00
Students gather, evaluate, and synthesis information from different sources.	32	2.00	0.00	0.00
Logically connect between ideas, contents, concepts, and area of learnings.	32	2.00	0.00	0.00
Students use integrated knowledge to solve problems logically.	32	1.13	0.24	0.49
Students reflect on their own beliefs, values and points of views from local and global perspectives.	32	1.03	0.03	0.18
Students use extensive range of resources and technologies independently.	32	1.00	0.00	0.00
Students set clear and challenging targets that consistently be achieved and adapted in the light of experience.	32	1.00	0.00	0.00
Students reflect and evaluate their own learning and outcomes of that learning.	32	1.03	0.03	0.18
Students generate innovative ideas and ways of thinking in solving problems.	32	2.00	0.00	0.00

Students use an extensive range of subjects' techniques as part of the creative process.	32	2.00	0.00	0.00
Students are open to challenges, difficulties and risk-taking	32	2.06	0.06	0.25
Students complete a research or open-ended investigation into a complex topic using higher-order thinking skills (analysis, synthesis, critical thinking, and creativity) to support their solutions and claims.	32	2.00	0.00	0.00
Students use technology to provide innovative solutions for problems that fit to the purpose.	32	1.00	0.00	0.00
Students solve an ample range of problems between well- and ill-structured.	32	2.00	0.00	0.00
Students communicate using an extensive range of methods: verbal, written, visual, and/or non-verbal.	32	1.03	0.03	0.18
Students organize the content of their thoughts and communication into a logical and coherent whole	32	2.00	0.00	0.00
Students use a wide range of modern technologies effectively and confidently as a means of communication	32	1.03	0.03	0.18
Students work productively with others from a wide range of social and cultural backgrounds	32	2.00	0.00	0.00
Students argue a point of view respectfully when challenging the differing views of an individual or the team	32	1.03	0.03	0.18
Students work with others to guide, counsel and motivate team members to achieve team goals	32	1.03	0.03	0.18
Students initiate a range of simple and complex activities and tasks which advance their knowledge, understanding and skills	32	2.00	0.00	0.00
Students plan, define and work towards goals and targets without the need to be pushed, driven or managed by others	32	1.03	0.03	0.18
Students recognize opportunities for self-advancement and opportunities that will benefit others	32	1.03	0.03	0.18
Students take responsibility and make decisions to resolve issues	32	1.03	0.03	0.18

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.901	0.97	32

Appendix H: Analysis of "Students' responses in Pretest posttest control and experimental groups"

One Way ANOVA

Descriptive statistics to show the equivalence between pretest control group (males and females) and pretest experimental group (males and females)

Descriptive									
						95% Confidence Interval for Mean		Minimum	Maximum
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound		
Emancipatory	Female Control	20	3.7917	.39690	.08875	3.6059	3.9774	2.83	4.33
	Male Control	20	3.5583	.74785	.16722	3.2083	3.9083	1.00	4.33
	Female Experimental	20	3.2000	.53694	.12006	2.9487	3.4513	2.17	4.00
	Male Experimental	20	3.2667	.97092	.21710	2.8123	3.7211	1.83	5.00
	Total	80	3.4542	.72478	.08103	3.2929	3.6155	1.00	5.00
Instrumental	Female Control	20	3.4667	.32264	.07214	3.3157	3.6177	2.83	4.17
	Male Control	20	3.6667	.60456	.13518	3.3837	3.9496	2.33	5.00
	Female Experimental	20	3.5000	.34199	.07647	3.3399	3.6601	2.83	4.50
	Male Experimental	20	3.9083	.54739	.12240	3.6521	4.1645	3.00	5.00
	Total	80	3.6354	.49405	.05524	3.5255	3.7454	2.33	5.00
Communicative	Female Control	20	3.4143	.56557	.12647	3.1496	3.6790	2.43	4.57

	Male Control	20	3.6857	.96178	.21506	3.2356	4.1358	1.00	5.00
	Female Experimental	20	3.7571	.42251	.09448	3.5594	3.9549	3.00	5.00
	Male Experimental	20	3.3857	.84719	.18944	2.9892	3.7822	1.71	5.00
	Total	80	3.5607	.73611	.08230	3.3969	3.7245	1.00	5.00

Descriptive statistics that shows the differences in the mean and standard deviation between the pretest and posttest control and experimental groups

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Emancipatory	Pre control	40	3.6750	.60264	.09529	3.4823	3.8677	1.00	4.33
	pre experimental	40	3.2333	.77515	.12256	2.9854	3.4812	1.83	5.00
	post control	40	3.1208	1.31233	.20750	2.7011	3.5405	1.00	5.00
	post experimental	40	4.3042	.47123	.07451	4.1535	4.4549	3.17	5.00
	Total	160	3.5833	.96479	.07627	3.4327	3.7340	1.00	5.00
Instrumental	Pre control	40	3.5667	.48891	.07730	3.4103	3.7230	2.33	5.00
	pre experimental	40	3.7042	.49569	.07838	3.5456	3.8627	2.83	5.00
	post control	40	2.9938	1.15322	.18234	2.6249	3.3626	1.00	4.75
	post experimental	40	4.2458	.47590	.07525	4.0936	4.3980	3.17	5.00
	Total	160	3.6276	.83683	.06616	3.4969	3.7583	1.00	5.00
Communicative	Pre control	40	3.5500	.79081	.12504	3.2971	3.8029	1.00	5.00
	pre experimental	40	3.5714	.68703	.10863	3.3517	3.7912	1.71	5.00
	post control	40	3.0286	1.30498	.20634	2.6112	3.4459	1.00	5.00

	post experimental	40	4.3964	.44883	.07097	4.2529	4.5400	3.43	5.00
	Total	160	3.6366	.98869	.07816	3.4822	3.7910	1.00	5.00

T-test

Comparison of descriptive statistics between pretest control group and pretest experimental group

Group Statistics					
	Groups	N	Mean	Std. Deviation	Std. Error Mean
Emancipatory	Pretest control	40	3.5208	.58127	.09191
	Pretest experimental	40	3.4708	.59424	.09396
Instrumental	Pretest control	40	3.2667	.70286	.11113
	Pretest experimental	40	3.0000	.78899	.12475
Communicative	Pretest control	40	3.5500	.79081	.12504
	Pretest experimental	40	3.0000	1.05326	.16654

Comparison of descriptive statistics between posttest control group and posttest experimental group

Group Statistics					
	Groups	N	Mean	Std. Deviation	Std. Error Mean
Emancipatory	Posttest control	40	3.1208	1.31233	.20750
	Posttest experimental	40	4.3042	.47123	.07451
Instrumental	Posttest control	40	3.0208	1.22311	.19339
	Posttest experimental	40	4.2458	.47590	.07525
Communicative	Posttest control	40	3.0286	1.30498	.20634
	Posttest experimental	40	4.3964	.44883	.07097

Comparison of descriptive statistics between pretest and posttest control group

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Emancipatory	Control pretest	3.5208	40	.58127	.09191
	Control posttest	3.1208	40	1.31233	.20750
Instrumental	Control pretest	3.2667	40	.70286	.11113
	Control posttest	3.0208	40	1.22311	.19339
Communicative	Control pretest	3.5500	40	.79081	.12504
	Control posttest	3.0286	40	1.30498	.20634

Comparison of descriptive statistics between pretest and posttest experimental group

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Emancipatory	Experimental pretest	2.8375	40	.83844	.13257
	Experimental posttest	4.3042	40	.47123	.07451
Instrumental	Experimental pretest	3.0000	40	.78899	.12475
	Experimental posttest	4.2458	40	.47590	.07525
Communicative	Experimental pretest	3.0000	40	1.05326	.16654
	Experimental posttest	4.3964	40	.44883	.07097

Comparison of descriptive statistics between males and females of the posttest control group

Group Statistics					
	Groups	N	Mean	Std. Deviation	Std. Error Mean
Emancipatory	Male post control	20	1.9750	.72199	.16144
	Female post control	20	4.2667	.49971	.11174
Instrumental	Male post control	20	2.0250	.74196	.16591
	Female post control	20	4.0167	.65761	.14705
Communicative	Male post control	20	2.0071	.82714	.18495
	Female post control	20	4.0500	.78421	.17535

Comparison of descriptive statistics between males and females of the posttest experimental group

Group Statistics					
	Groups	N	Mean	Std. Deviation	Std. Error Mean
Emancipatory	Male posttest experimental	20	4.3917	.48145	.10766
	Female posttest experimental	20	4.2167	.45595	.10195
Instrumental	Male posttest experimental	20	4.2000	.50610	.11317
	Female posttest experimental	20	4.2917	.45201	.10107
Communicative	Male posttest experimental	20	4.4214	.46459	.10389
	Female posttest experimental	20	4.3714	.44311	.09908

Multiple Regression

Descriptive Statistics

	Mean	Std. Deviation	N
Experimental_Marks	99.2831	1.60056	42
Emancipatory_E	99.3786	1.31222	42
Instrumental_E	99.4157	1.28736	42
Communicative_E	99.2019	1.50423	42

Correlations

		Experimental_Marks	Emancipatory_E	Instrumental_E	Communicative_E
Pearson Correlation	Experimental_Marks	1.000	.689	.669	.863
	Emancipatory_E	.689	1.000	.875	.627
	Instrumental_E	.669	.875	1.000	.517
	Communicative_E	.863	.627	.517	1.000
Sig. (1-tailed)	Experimental_Marks	.	.000	.000	.000
	Emancipatory_E	.000	.	.000	.000
	Instrumental_E	.000	.000	.	.000
	Communicative_E	.000	.000	.000	.
N	Experimental_Marks	42	42	42	42
	Emancipatory_E	42	42	42	42
	Instrumental_E	42	42	42	42
	Communicative_E	42	42	42	42

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Communicative_E, Instrumental_E, Emancipatory_E[b]	.	Enter

a. Dependent Variable: Experimental_Marks

b. All requested variables entered.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin–Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.903[a]	.815	.800	.71503	.815	55.812	3	38	.000	2.275

a. Predictors: (Constant), Communicative_E, Instrumental_E, Emancipatory_E

b. Dependent Variable: Experimental_Marks

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	85.605	3	28.535	55.812	.000[b]
	Residual	19.428	38	.511		
	Total	105.033	41			

a. Dependent Variable: Experimental_Marks

b. Predictors: (Constant), Communicative_E, Instrumental_E, Emancipatory_E

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	-12.478	9.281		-1.344	.187	-31.267	6.311					
	Emancipatory_E	-.125	.193	-.103	-.648	.521	-.517	.266	.689	-.105	-.045	.193	5.170
	Instrumental_E	.474	.180	.381	2.638	.012	.110	.837	.669	.393	.184	.233	4.284
	Communicative_E	.778	.096	.731	8.132	.000	.584	.971	.863	.797	.567	.603	1.659

a. Dependent Variable: Experimental_Marks

Coefficient Correlations[a]

Model			Communicative_E	Instrumental_E	Emancipatory_E
1	Correlations	Communicative_E	1.000	.082	-.421
		Instrumental_E	.082	1.000	-.825
		Emancipatory_E	-.421	-.825	1.000
	Covariances	Communicative_E	.009	.001	-.008
		Instrumental_E	.001	.032	-.029
		Emancipatory_E	-.008	-.029	.037

a. Dependent Variable: Experimental_Marks

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	Emancipatory_E	Instrumental_E	Communicative_E
1	1	4.000	1.000	.00	.00	.00	.00
	2	.000	187.373	.48	.00	.01	.69
	3	.000	198.144	.50	.07	.11	.20
	4	1.907E-5	457.948	.02	.93	.89	.11

a. Dependent Variable: Experimental_Marks

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	94.4735	100.2089	99.2831	1.44496	42
Residual	-1.61915	1.66784	.00000	.68837	42
Std. Predicted Value	-3.329	.641	.000	1.000	42
Std. Residual	-2.264	2.333	.000	.963	42

a. Dependent Variable: Experimental_Marks

Appendix I: Comparison between lesson plans of the courses and graduation projects

Lesson Plans Analysis of AutoCAD, Electrical Principles and Robotics		
Know		
Level of Knowledge (Knowledge integration)	**Assessment Design**	**Guided Questions**
The important contents for students to know have been identified. In all lesson plans, the level of knowledge is identified where the focus is on the concepts, enduring understanding, and principles and theories which are considered to be higher level of knowledge. There are two of the lesson plans who failed to identify the enduring understanding or the big idea of the lesson. However, there was connection between what they are doing to the real-life. These have been shown in the AutoCAD course where the lessons were focusing on drawing 2D and 3D modelling using technology and mathematics contents. The degree of integration designed to be the strongest integration which is known as the third way of Dugger and Fellow (2011) framework. It implies in integrating all subjects (science, technology, art, and mathematics) within the engineering course.	The assessments were authentic tasks in shape of projects, real-life problems, performance tasks, etc. It provides ways to celebrate learning were some students reflect on their work and present achievements to their peers. In addition to the bonus given to them in innovating and extending their learning. Handouts of instructions and rubrics were handed to students in order to know what is expected from them. The pace of assessments is broadly even where it allows students to rest and plan ahead. The lesson plans of the courses did not mention if the assessment requires an external audience to assess the students' performance.	The guided questions used in the lesson plans provide a framework for the lesson, guide students' learning, encourage inquiry and multiple answers, and encompass a substantial part of the lesson. Few lessons were not built on students' interests. However, the main points for the next lesson are discussed with student and ideas for homework are offered to them so they can choose from. Teachers wrote students' feedback on the lesson plans for further improvement of the lesson. Some lessons were mentioning the extension of students' learning to future work that shows within the closure of the lessons.

DO			
Level of Skills	**Emancipatory Learning**	**Instrumental Learning**	**Communicative Learning**
The focus of all lessons was on the discipline specific skills and interdisciplinary skills. Students are producers of knowledge through information management, research, critical thinking, communication, and problem-solving. The performance based assessments in all lesson plans include meaningful and relevant indicators of quality performances. All lesson plans mentioned the kind of assessments used to assess students' integrated knowledge and skills.	The students' self-assessment, peer assessment, rubrics, and observation are used in all lesson plans. In addition to these assessments, the robotics lessons used also performance tasks and journals as essential assessments. The opportunity for students' writing tasks were shown in the robotics course and lacked in the other courses.	The activities in all lesson plans used engage students in instrumental learning through inquiry and problem-solving tasks. There are enough variety and choices of activities to address diverse learning needs. Most of activities are connected to the guiding questions and aligned to the objectives however, few of them are aligned only to the objectives as the guiding questions were missed. The activities are aligned to the culminating assessment and KDB model.	All Lesson plans requires students to work individually and in a communicative learning environment. Students have to work with their peers in order to complete authentic tasks that require communication and collaboration. In addition, it was planned that they have to teach each other and clarify concepts when needed within their groups.
BE			
Teachers mentioned that students by end of each lesson acquire some habits and values such as respect, teamwork, and citizenship. Teachers plan the lessons for students to demonstrate self-direction, reflection, cooperation, self-evaluation, making good choices, and being inviting to others. Each lesson plan includes time for students' post conference where they discuss feedback and setting plans to improve their work. The laboratory tasks mentioned in the lesson plans were full of independence learning where students are engaged in communicative and reflective learning. Robotics course has the highest number of authentic assessment tasks used and highest integration between subjects.			

Lesson Plans Analysis of Graduation Project		
Know		
Level of Knowledge (Knowledge integration)	**Assessment Design**	**Guided Questions**
It has been identified clearly the important contents and knowledge students should know. Regarding the level of knowledge, the focus was on the highest level that involves: concepts, enduring understanding, and principles and theories. However, the facts and topics that are considered to be the lowest level were not mentioned in the graduation project lesson plans. It was clear that the integration between subjects are very strong and is the highest level of integration.	The formative assessments used are reflecting the Know, Do, and Be bridge where there is alignment between the assessments and the desired outcomes. In addition, it provides various ways to celebrate learning. Furthermore, rubrics and handouts of instructions are shared with the students in advance. Interestingly important to note that the kind of assessments used require external audience to assess the students' performance. The pace of assessments is broadly even and allow to rest and plan ahead.	The guided questions used provide a framework that guide students' learning. It encourages inquiry and multiple answers where students can think divergently. It encompasses a substantial part of the unit and connected to students' interests.

DO			
Level of Skills	**Emancipatory Learning**	**Instrumental Learning**	**Communicative Learning**

All the levels of skills are identified in objectives of the lesson plans. However, the focus is on the highest of them which is the interdisciplinary skills that require complex performances and use the information through mastering the following skills: information management, inquiry, critical thinking, communication, and problem-solving. The other high level of skills identified in the lesson plans is the discipline specific skills where it requires students to be actively engaged in the learning processes where they construct and interpret, design, compare, perform, and create. The performance-based assessments include meaningful and relevant indicators of quality performances. The kind of assessments used allow students to integrate between the knowledge and the skills such as: self-assessment, peer assessment, performance tasks, rubrics, journals, portfolios, observations, and checklists.	Opportunities of students' writing is mentioned clearly in the lesson where they have to record steps and reflect using their iPad and/or journal. The process of the projects was discussed with the students and raising awareness about the stages of the projects took place.	The types of activities used is reflecting the instrumental learning approach where they inquire and solve complex problems. In addition, the various activities used address the diverse learning needs. The activities are connected to the objective and the learning outcomes of the projects, the culminating assessments, and the KDB model. Students are leading the learning process where they have to identify the problem; suggesting ideas; discussing the freehand drawings, research, complete AutoCAD drawings; formulate surveys; and presenting their plans.	The activities are connected to the objective and the learning outcomes of the projects, the culminating assessments, and the KDB model. It allows for the communicative learning. The use of authentic assessment is an essential part of learning process. The questions in students' collaborative work were expected by teachers and planning were provided accordingly. The latest mechanical machines were provided to students with special trainers and experts. Students have the opportunity to experience different careers through their projects and help in the completion of their projects. A dialogue between students to students and students to teachers were mentioned in the plans in order to give opportunity to feedback, reflect critically, and change their perspectives.
BE			
Some values and habits were identified in the lesson plans where the aim is to develop the teamwork, learning and innovation, personal and social, national and global citizenship skills. The students demonstrate the self-direction in their learning process, reflection on their work, setting their own goals; cooperate together; self-evaluate their work; and making good choices. All the lesson plans involve time for students post conference where they receive feedback and set plans to improve their work. In addition to the regular feedback students receive from their peers and from their teachers. Extension to future learning is considered in the lesson plans. The group discussions and experimental learning took place in the learning process where they learn from their mistakes (failure-driven approach).			

Appendix J: Curriculum Developers' and Teachers' Questionnaire

Demographic Information

What is the highest level of education you have completed?	Bachelor's Degree	Master's Degree	Professional Degree	Doctorate Degree
Science	8.77%	10.53%	1.75%	1.75%
Technology & Design Art	8.77%	3.51%	3.51%	0.00%
Engineering	10.53%	7.02%	1.75%	5.26%
Language Art	7.02%	8.77%	1.75%	0.00%
Mathematics	8.77%	8.77%	3.51%	0.00%
Total	43.86%	38.60%	12.28%	7.02%

What is your gender?	Male	Female
Science	10.53%	10.53%
Technology & Design Art	7.02%	8.77%
Engineering	10.53%	14.04%
Language Art	8.77%	8.77%
Mathematics	3.51%	17.54%
Total	40.35%	59.65%

How many years of experience do you have?	0-5	6 to 10	11 to 15	16 to 20
Science	1.75%	5.26%	12.28%	1.75%
Technology & Design Art	5.26%	7.02%	3.51%	0.00%
Engineering	5.26%	1.75%	14.04%	3.51%
Language Art	0.00%	5.26%	7.02%	5.26%
Mathematics	3.51%	5.26%	7.02%	5.26%
Total	15.79%	24.56%	43.86%	15.79%

What is your position & specialization?	Curriculum Developer	Coordinator	Lead Teacher	Teacher
Science	3.51%	0.00%	7.02%	14.04%
Technology & Design Art	0.00%	1.75%	0.00%	10.53%
Engineering	7.02%	5.26%	1.75%	12.28%
Language Art	3.51%	0.00%	1.75%	10.53%
Mathematics	3.51%	7.02%	1.75%	8.77%
Total	17.54%	14.04%	12.28%	56.14%

Transdisciplinary curriculum design using authentic assessment	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Science	55.77%	34.62%	6.41%	3.21%	0.00%

Technology & Design	41.03%	48.72%	7.69%	2.56%	0.00%
Engineering	63.19%	28.57%	6.59%	1.65%	0.00%
Language Art	40.00%	47.69%	7.69%	4.62%	0.00%
Mathematics	39.10%	41.03%	16.03%	3.21%	0.64%

Emancipatory Learning (Critical Thinking Skills)	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Science	50.00%	41.67%	8.33%	0.00%	0.00%
Technology & Design	38.89%	5.78%	8.33%	0.00%	0.00%
Engineering	60.71%	32.14%	3.57%	3.57%	0.00%
Language Art	47.50%	47.50%	5.00%	0.00%	0.00%
Mathematics	45.83%	39.58%	14.58%	0.00%	0.00%

Emancipatory Learning (Independent Learning Skills)	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Science	55.56%	33.33%	8.33%	2.78%	0.00%
Technology & Design	33.33%	59.26%	3.70%	3.70%	0.00%
Engineering	78.57%	19.05%	2.38%	0.00%	0.00%
Language Art	40.00%	50.00%	6.67%	3.33%	0.00%
Mathematics	44.44%	38.98%	16.67%	0.00%	0.00%

Instrumental Learning (Creativity & Innovation Skills)	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Science	52.78%	33.33%	13.89%	0.00%	0.00%
Technology & Design	40.74%	51.85%	7.41%	0.00%	0.00%
Engineering	61.09%	35.71%	2.38%	0.00%	0.00%
Language Art	40.00%	43.33%	16.67%	0.00%	0.00%
Mathematics	38.89%	41.67%	16.67%	2.78%	0.00%

Instrumental Learning (Problem Solving Skills)	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Science	55.56%	33.33%	11.11%	0.00%	0.00%
Technology & Design	37.04%	55.56%	7.41%	0.00%	0.00%
Engineering	76.19%	23.81%	0.00%	0.00%	0.00%
Language Art	36.67%	46.67%	16.67%	0.00%	0.00%
Mathematics	44.44%	44.44%	11.11%	0.00%	0.00%

Communicative Learning (Communication Skills)	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Science	59.45%	34.87%	5.68%	0.00%	0.00%
Technology & Design	40.74%	55.56%	3.70%	0.00%	0.00%
Engineering	80.95%	19.05%	0.00%	0.00%	0.00%
Language Art	56.67%	30.00%	13.33%	0.00%	0.00%
Mathematics	69.44%	22.22%	8.33%	0.00%	0.00%

Communicative Learning (Collaboration Skills)	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Science	58.33%	27.78%	13.89%	0.00%	0.00%
Technology & Design	48.15%	40.74%	11.11%	0.00%	0.00%
Engineering	69.05%	23.81%	7.14%	0.00%	0.00%
Language Art	50.00%	36.67%	13.33%	0.00%	0.00%
Mathematics	50.00%	33.33%	16.67%	0.00%	0.00%

Communicative Learning (Self-direction Skills)	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Science	66.67%	25.00%	8.33%	0.00%	0.00%
Technology & Design	33.33%	58.33%	8.33%	0.00%	0.00%
Engineering	80.36%	16.07%	0.00%	35.70%	0.00%
Language Art	57.50%	22.50%	20.00%	0.00%	0.00%
Mathematics	56.25%	27.08%	16.67%	0.00%	0.00%

Curriculum Developer Responses

Curriculum & Assessment Design	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
1. Integration between disciplines allows for more concepts that can be taught in less time and in higher levels	21	2.00	3.00	5.00	4.5238	.60159	.362
2. Shift from STEM to STEAM allow students to think divergently where each create different product based on their points of views	21	2.00	3.00	5.00	4.5238	.60159	.362
3. Design of transdisciplinary curriculum relates closely to career goals and practice	21	2.00	3.00	5.00	4.6667	.57735	.333
4. The course requirements, instructional activities, and assessments are designed to a certain degree that allow students to experience the fidelity of authentic tasks.	21	3.00	2.00	5.00	4.2381	.76842	.590

5. The design of transdisciplinary curriculum using authentic assessment afford students' engagement and active learning.	21	1.00	4.00	5.00	4.6190	.49761	.248
6. The design of transdisciplinary curriculum using authentic assessment provide challenge, interest, and motivation to learn.	21	1.00	4.00	5.00	4.5714	.50709	.257
7. Transdisciplinary curriculum focuses on different ways of looking at the world	21	2.00	3.00	5.00	4.4762	.67964	.462
8. The authentic assessment is designed to give students feedback in a more motivational form.	21	3.00	2.00	5.00	4.3810	.92066	.848
9. Authentic assessments take time at both creation and grading stages.	21	1.00	4.00	5.00	4.5714	.50709	.257
10. Students do not learn the same way; accordingly, they are not assessed the same way.	21	4.00	1.00	5.00	3.9048	1.33809	1.790
11. Each activity in authentic assessment includes detailed instructions and guidelines for students to ensure the completion of the requirements.	21	3.00	2.00	5.00	4.0000	1.14018	1.300
12. Authentic assessment aims to connect between contents and apply new knowledge into meaningful and relevant tasks.	21	1.00	4.00	5.00	4.5714	.50709	.257
13. An indicator of students' attainment to their knowledge, skills, and attitudes is completing relevant activities and investigations.	21	2.00	3.00	5.00	4.3810	.66904	.448
Emancipatory (Critical Thinking Skills)	**N**	**Range**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Variance**
1. Students gather, evaluate, and synthesis information from different sources.	22	1.00	4.00	5.00	4.4545	.50965	.260
2. Logically connect between ideas, contents, concepts, and area of learnings.	22	2.00	3.00	5.00	4.2273	.68534	.470
3. Students use integrated knowledge to solve problems logically.	22	2.00	3.00	5.00	4.3182	.71623	.513
4. Students reflect on their own beliefs, values and points of views from local and global perspectives.	22	2.00	3.00	5.00	4.4545	.67098	.450
Emancipatory Learning (Independent Learning Skills)	**N**	**Range**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Variance**
5. Students use extensive range of resources and technologies independently.	21	2.00	3.00	5.00	4.5714	.59761	.357
6. Students set clear and challenging targets that consistently be achieved and adapted in the light of experience.	21	3.00	2.00	5.00	4.4286	.81064	.657
7. Students reflect and evaluate their own learning and outcomes of that learning.	21	2.00	3.00	5.00	4.5238	.67964	.462

Instrumental Learning (Creativity & Innovation Skills)	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
1. Students generate innovative ideas and ways of thinking in solving problems.	21	1.00	4.00	5.00	4.5714	.50709	.257
2. Students use an extensive range of subjects' techniques as part of the creative process.	21	2.00	3.00	5.00	4.3810	.66904	.448
3. Students are open to challenges, difficulties and risk-taking	21	2.00	3.00	5.00	4.5238	.67964	.462
Instrumental Learning Problem-solving Skills)	**N**	**Range**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Variance**
4. Students complete a research or open-ended investigation into a complex topic using higher-order thinking skills (analysis, synthesis, critical thinking, and creativity) to support their solutions and claims.	21	2.00	3.00	5.00	4.4762	.67964	.462
5. Students use technology to provide innovative solutions for problems that fit to the purpose.	21	2.00	3.00	5.00	4.4286	.74642	.557
6. Students solve an ample range of problems between well- and ill-structured.	21	2.00	3.00	5.00	4.5238	.67964	.462
Communicative Learning (Communication Skills)	**N**	**Range**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Variance**
1. Students communicate using an extensive range of methods: verbal, written, visual, and/or non-verbal.	21	2.00	3.00	5.00	4.6667	.57735	.333
2. Students organize the content of their thoughts and communication into a logical and coherent whole	21	2.00	3.00	5.00	4.6667	.57735	.333
3. Students use a wide range of modern technologies effectively and confidently as a means of communication	21	2.00	3.00	5.00	4.6190	.58959	.348
Communicative Learning (Collaboration Skills)	**N**	**Range**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Variance**
4. Students work productively with others from a wide range of social and cultural backgrounds	21	2.00	3.00	5.00	4.2857	.84515	.714
5. Students argue a point of view respectfully when challenging the differing views of an individual or the team	21	2.00	3.00	5.00	4.5714	.59761	.357
6. Students work with others to guide, counsel and motivate team members to achieve team goals	21	2.00	3.00	5.00	4.6190	.58959	.348
Communicative Learning (Self-direction Skills)	**N**	**Range**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Variance**
7. Students initiate a range of simple and complex activities and tasks which advance their knowledge, understanding and skills	21	2.00	3.00	5.00	4.6667	.65828	.433

8. Students plan, define and work towards goals and targets without the need to be pushed, driven or managed by others	21	2.00	3.00	5.00	4.5714	.67612	.457
9. Students recognize opportunities for self-advancement and opportunities that will benefit others	21	2.00	3.00	5.00	4.6667	.65828	.433
10. Students take responsibility and make decisions to resolve issues	21	2.00	3.00	5.00	4.5714	.67612	.457

The Percentage of Curriculum Developers' Responses

Section 2: Curriculum and Assessment Design **To what extent do you agree with the following while designing and planning transdisciplinary curriculum with authentic assessment: Integration between disciplines allows for more concepts that can be taught in less time and in higher levels**	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Integration between disciplines allows for more concepts that can be taught in less time and in higher levels	57.14%	38.10%	4.76%	0.00%	0.00%
Shift from STEM to STEAM allow students to think divergently where each create different product based on their points of views	57.14%	38.10%	4.76%	0.00%	0.00%
Design of transdisciplinary curriculum relates closely to career goals and practice	71.43%	23.81%	4.76%	0.00%	0.00%
The course requirements, instructional activities, and assessments are designed to a certain degree that allow students to experience the fidelity of authentic tasks.	38.10%	52.38%	4.76%	4.76%	0.00%
The design of transdisciplinary curriculum using authentic assessment afford students' engagement and active learning.	61.90%	38.10%	0.00%	0.00%	0.00%
The design of transdisciplinary curriculum using authentic assessment provide challenge, interest, and motivation to learn.	57.14%	42.86%	0.00%	0.00%	0.00%
Transdisciplinary curriculum focuses on different ways of looking at the world	57.14%	33.33%	9.52%	0.00%	0.00%
The authentic assessment is designed to give students feedback in a more motivational form.	57.14%	33.33%	0.00%	9.52%	0.00%
Authentic assessments take time at both creation and grading stages.	57.14%	42.86%	0.00%	0.00%	0.00%
Students do not learn the same way; accordingly, they are not assessed the same way.	47.62%	23.81%	4.76%	19.05%	4.76%
Each activity in authentic assessment includes detailed instructions and guidelines for students to ensure the completion of the requirements.	42.86%	33.33%	4.76%	19.05%	0.00%
Authentic assessment aims to connect between contents and apply new knowledge into meaningful and relevant tasks.	42.86%	57.14%	0.00%	0.00%	0.00%
An indicator of students' attainment to their knowledge, skills, and attitudes is completing relevant activities and investigations.	47.62%	42.86%	9.52%	0.00%	0.00%

Emancipatory Learning (Reflective Learning):
To what extent do you agree in integrating the following skills while planning instructional activities: Students set clear and challenging targets that consistently be achieved and adapted in the light of experience.

A. Critical Thinking	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Students gather, evaluate, and synthesis information from different sources.	47.62%	52.38%	0.00%	0.00%	0.00%
Logically connect between ideas, contents, concepts, and area of learnings.	33.33%	52.38%	14.29%	0.00%	0.00%
Students use integrated knowledge to solve problems logically.	42.86%	42.86%	14.29%	0.00%	0.00%
Students reflect on their own beliefs, values and points of views from local and global perspectives.	57.14%	33.33%	9.52%	0.00%	0.00%

B. Independent Learning:	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Students use extensive range of resources and technologies independently.	61.90%	33.33%	4.76%	0.00%	0.00%
Students set clear and challenging targets that consistently be achieved and adapted in the light of experience.	57.14%	33.33%	4.76%	4.76%	0.00%
Students reflect and evaluate their own learning and outcomes of that learning.	61.90%	28.57%	9.52%	0.00%	0.00%
Instrumental Learning: **To what extent do you agree in integrating the following skills while planning instructional activities: Students use an extensive range of subjects' techniques as part of the creative process.**					
A. Creativity and Innovation	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Students generate innovative ideas and ways of thinking in solving problems.	57.14%	42.86%	0.00%	0.00%	0.00%
Students use an extensive range of subjects' techniques as part of the creative process.	47.62%	42.86%	9.52%	0.00%	0.00%
Students are open to challenges, difficulties and risk-taking	61.90%	28.57%	9.52%	0.00%	0.00%
B. Problem Solving	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Students complete a research or open-ended investigation into a complex topic using higher-order thinking skills (analysis, synthesis, critical thinking, and creativity) to support their solutions and claims.	57.14%	33.33%	9.52%	0.00%	0.00%
Students use technology to provide innovative solutions for problems that fit to the purpose.	57.14%	28.57%	14.29%	0.00%	0.00%
Students solve an ample range of problems between well- and ill-structured.	61.90%	28.57%	9.52%	0.00%	0.00%
Communicative Learning: **To what extent do you agree in integrating the following skills while planning instructional activities: Students communicate using an extensive range of methods: verbal, written, visual, and/or non-verbal.**					
A. Communication	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Students communicate using an extensive range of methods: verbal, written, visual, and/or non-verbal.	71.43%	23.81%	4.76%	0.00%	0.00%
Students organize the content of their thoughts and communication into a logical and coherent whole	71.43%	23.81%	4.76%	0.00%	0.00%
Students use a wide range of modern technologies effectively and confidently as a means of communication	66.67%	28.57%	4.76%	0.00%	0.00%
B. Collaboration	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Students work productively with others from a wide range of social and cultural backgrounds	52.38%	23.81%	23.81%	0.00%	0.00%
Students argue a point of view respectfully when challenging the differing views of an individual or the team	61.90%	33.33%	4.76%	0.00%	0.00%
Students work with others to guide, counsel and motivate team members to achieve team goals	66.67%	28.57%	4.76%	0.00%	0.00%
C. Self-direction	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Students initiate a range of simple and complex activities and tasks which advance their knowledge, understanding and skills	76.19%	14.29%	9.52%	0.00%	0.00%

Students plan, define and work towards goals and targets without the need to be pushed, driven or managed by others	66.67%	23.81%	9.52%	0.00%	0.00%
Students recognize opportunities for self-advancement and opportunities that will benefit others	76.19%	14.29%	9.52%	0.00%	0.00%
Students take responsibility and make decisions to resolve issues	66.67%	23.81%	9.52%	0.00%	0.00%

Teachers' Responses
Curriculum & Assessment Design

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
1. Integration between disciplines allows for more concepts that can be taught in less time and in higher levels	30	3.00	2.00	5.00	4.2667	.90719	.823
2. Shift from STEM to STEAM allow students to think divergently where each create different product based on their points of views	30	2.00	3.00	5.00	4.3333	.66089	.437
3. Design of transdisciplinary curriculum relates closely to career goals and practice	30	2.00	3.00	5.00	4.1000	.71197	.507
4. The course requirements, instructional activities, and assessments are designed to a certain degree that allow students to experience the fidelity of authentic tasks.	30	3.00	2.00	5.00	4.0333	.85029	.723
5. The design of transdisciplinary curriculum using authentic assessment afford students' engagement and active learning.	30	4.00	1.00	5.00	3.9667	1.06620	1.137
6. The design of transdisciplinary curriculum using authentic assessment provide challenge, interest, and motivation to learn.	30	3.00	2.00	5.00	4.2333	.93526	.875
7. Transdisciplinary curriculum focuses on different ways of looking at the world	30	3.00	2.00	5.00	3.9667	1.15917	1.344
8. The authentic assessment is designed to give students feedback in a more motivational form.	30	3.00	2.00	5.00	4.0667	.90719	.823
9. Authentic assessments take time at both creation and grading stages.	30	3.00	2.00	5.00	4.1000	.99481	.990
10. Students do not learn the same way; accordingly, they are not assessed the same way.	30	3.00	2.00	5.00	3.8000	1.21485	1.476
11. Each activity in authentic assessment includes detailed instructions and guidelines for students to ensure the completion of the requirements.	30	3.00	2.00	5.00	3.9333	1.11211	1.237
12. Authentic assessment aims to connect between contents and apply new knowledge into meaningful and relevant tasks.	30	3.00	2.00	5.00	4.0667	1.01483	1.030
13. An indicator of students' attainment to their knowledge, skills, and attitudes is completing relevant activities and investigations.	30	3.00	2.00	5.00	4.2333	1.00630	1.013

Emancipatory Learning

Critical Thinking	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
1. Students gather, evaluate, and synthesis information from different sources.	30	2.00	3.00	5.00	4.5000	.57235	.328
2. Logically connect between ideas, contents, concepts, and area of learnings.	30	3.00	2.00	5.00	4.2667	.78492	.616
3. Students use integrated knowledge to solve problems logically.	30	3.00	2.00	5.00	4.3667	.85029	.723
4. Students reflect on their own beliefs, values and points of views from local and global perspectives.	30	2.00	3.00	5.00	4.5000	.57235	.328
Independent Learning	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
5. Students use extensive range of resources and technologies independently.	30	2.00	3.00	5.00	4.4333	.67891	.461
6. Students set clear and challenging targets that consistently be achieved and adapted in the light of experience.	30	2.00	3.00	5.00	4.2000	.66436	.441
7. Students reflect and evaluate their own learning and outcomes of that learning.	30	4.00	1.00	5.00	4.1667	1.08543	1.178

Instrumental Learning

Creativity & Innovation	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
1. Students generate innovative ideas and ways of thinking in solving problems.	30	2.00	3.00	5.00	4.3333	.66089	.437
2. Students use an extensive range of subjects' techniques as part of the creative process.	30	2.00	3.00	5.00	4.2667	.73968	.547
3. Students are open to challenges, difficulties and risk-taking	30	2.00	3.00	5.00	4.2333	.67891	.461
Problem Solving	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
4. Students complete a research or open-ended investigation into a complex topic using higher-order thinking skills (analysis, synthesis, critical thinking, and creativity) to support their solutions and claims.	30	2.00	3.00	5.00	4.4000	.62146	.386
5. Students use technology to provide innovative solutions for problems that fit to the purpose.	30	4.00	1.00	5.00	4.4000	.85501	.731
6. Students solve an ample range of problems between well- and ill-structured.	30	2.00	3.00	5.00	4.1667	.69893	.489
Valid N (listwise)	30						

Communicative Learning

Communication	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
1. Students communicate using an extensive range of methods: verbal, written, visual, and/or non-verbal.	30	2.00	3.00	5.00	4.5000	.57235	.328
2. Students organize the content of their thoughts and communication into a logical and coherent whole	30	2.00	3.00	5.00	4.5000	.68229	.466
3. Students use a wide range of modern technologies effectively and confidently as a means of communication	30	2.00	3.00	5.00	4.5000	.62972	.397
Collaboration	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
4. Students work productively with others from a wide range of social and cultural backgrounds	30	2.00	3.00	5.00	4.2667	.78492	.616
5. Students argue a point of view respectfully when challenging the differing views of an individual or the team	30	2.00	3.00	5.00	4.4000	.77013	.593
6. Students work with others to guide, counsel and motivate team members to achieve team goals	30	2.00	3.00	5.00	4.5667	.62606	.392
Self-direction	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
7. Students initiate a range of simple and complex activities and tasks which advance their knowledge, understanding and skills	30	4.00	1.00	5.00	4.3667	.96431	.930
8. Students plan, define and work towards goals and targets without the need to be pushed, driven or managed by others	30	3.00	2.00	5.00	4.2333	.81720	.668
9. Students recognize opportunities for self-advancement and opportunities that will benefit others	30	3.00	2.00	5.00	4.2667	.90719	.823
10. Students take responsibility and make decisions to resolve issues	30	2.00	3.00	5.00	4.4000	.67466	.455
Valid N (listwise)	30						

Percentage of Teachers' Responses

Section 2: Curriculum and Assessment Design **To what extent do you agree with the following while designing and planning transdisciplinary curriculum with authentic assessment: Integration between disciplines allows for more concepts that can be taught in less time and in higher levels**	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
I+A3:AE15ntegration between disciplines allows for more concepts that can be taught in less time and in higher levels	50.00%	33.33%	10.00%	6.67%	0.00%
Shift from STEM to STEAM allow students to think divergently where each create different product based on their points of views	43.33%	46.67%	10.00%	0.00%	0.00%
Design of transdisciplinary curriculum relates closely to career goals and practice	30.00%	50.00%	20.00%	0.00%	0.00%

The course requirements, instructional activities, and assessments are designed to a certain degree that allow students to experience the fidelity of authentic tasks.	30.00%	53.33%	13.33%	3.33%	0.00%
The design of transdisciplinary curriculum using authentic assessment afford students' engagement and active learning.	36.67%	53.33%	6.67%	3.33%	0.00%
The design of transdisciplinary curriculum using authentic assessment provide challenge, interest, and motivation to learn.	46.67%	50.00%	3.33%	0.00%	0.00%
Transdisciplinary curriculum focuses on different ways of looking at the world	43.33%	43.33%	6.67%	6.67%	0.00%
The authentic assessment is designed to give students feedback in a more motivational form.	36.67%	46.67%	16.67%	0.00%	0.00%
Authentic assessments take time at both creation and grading stages.	43.33%	43.33%	13.33%	0.00%	0.00%
Students do not learn the same way; accordingly, they are not assessed the same way.	40.00%	30.00%	13.33%	16.67%	0.00%
Each activity in authentic assessment includes detailed instructions and guidelines for students to ensure the completion of the requirements.	36.67%	50.00%	3.33%	10.00%	0.00%
Authentic assessment aims to connect between contents and apply new knowledge into meaningful and relevant tasks.	43.33%	36.67%	16.67%	3.33%	0.00%
An indicator of students' attainment to their knowledge, skills, and attitudes is completing relevant activities and investigations.	56.67%	23.33%	20.00%	0.00%	0.00%
Emancipatory Learning (Reflective Learning): **To what extent do you agree in integrating the following skills while planning instructional activities: Students gather, evaluate, and synthesis information from different sources.**					
A. Critical Thinking Skills:	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Students gather, evaluate, and synthesis information from different sources.	53.33%	43.33%	3.33%	0.00%	0.00%
Logically connect between ideas, contents, concepts, and area of learnings.	100.00%	100.00%	100.00%	100.00%	100.00%
Students use integrated knowledge to solve problems logically.	56.67%	26.67%	13.33%	3.33%	0.00%
Students reflect on their own beliefs, values and points of views from local and global perspectives.	53.33%	43.33%	3.33%	0.00%	0.00%
B. Independent Learning	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Students use extensive range of resources and technologies independently.	53.33%	36.67%	10.00%	0.00%	0.00%
Students set clear and challenging targets that consistently be achieved and adapted in the light of experience.	33.33%	53.33%	13.33%	0.00%	0.00%
Students reflect and evaluate their own learning and outcomes of that learning.	53.33%	36.67%	10.00%	0.00%	0.00%
Instrumental Learning: **To what extent do you agree in integrating the following skills while planning instructional activities: Students generate innovative ideas and ways of thinking in solving problems.**					
A. Creativity and Innovation	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Students generate innovative ideas and ways of thinking in solving problems.	43.33%	46.67%	10.00%	0.00%	0.00%
Students use an extensive range of subjects' techniques as part of the creative process.	43.33%	40.00%	16.67%	0.00%	0.00%
Students are open to challenges, difficulties and risk-taking	36.67%	46.67%	13.33%	3.33%	0.00%
B. Problem Solving	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree

Students complete a research or open-ended investigation into a complex topic using higher-order thinking skills (analysis, synthesis, critical thinking, and creativity) to support their solutions and claims.	46.67%	46.67%	6.67%	0.00%	0.00%
Students use technology to provide innovative solutions for problems that fit to the purpose.	56.67%	40.00%	3.33%	0.00%	0.00%
Students solve an ample range of problems between well- and ill-structured.	33.33%	50.00%	16.67%	0.00%	0.00%
Communicative Learning: **To what extent do you agree in integrating the following skills while planning instructional activities: Students communicate using an extensive range of methods: verbal, written, visual, and/or non-verbal.**					
A. Communication:	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Students communicate using an extensive range of methods: verbal, written, visual, and/or non-verbal.	53.33%	43.33%	3.33%	0.00%	0.00%
Students organize the content of their thoughts and communication into a logical and coherent whole	60.00%	30.00%	10.00%	0.00%	0.00%
Students use a wide range of modern technologies effectively and confidently as a means of communication	56.67%	36.67%	6.67%	0.00%	0.00%
B. Collaboration:	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Students work productively with others from a wide range of social and cultural backgrounds	46.67%	36.67%	16.67%	0.00%	0.00%
Students argue a point of view respectfully when challenging the differing views of an individual or the team	56.67%	26.67%	16.67%	0.00%	0.00%
Students work with others to guide, counsel and motivate team members to achieve team goals	63.33%	33.33%	3.33%	0.00%	0.00%
C. Self-direction:	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Students initiate a range of simple and complex activities and tasks which advance their knowledge, understanding and skills	60.00%	36.67%	3.33%	0.00%	0.00%
Students plan, define and work towards goals and targets without the need to be pushed, driven or managed by others	43.33%	40.00%	13.33%	3.33%	0.00%
Students recognize opportunities for self-advancement and opportunities that will benefit others	53.33%	23.33%	20.00%	3.33%	0.00%
Students take responsibility and make decisions to resolve issues	50.00%	40.00%	10.00%	0.00%	0.00%

Appendix K: Sample of Lesson Plan Template

SUBJECT/CODE		**TEACHER**		**CAMPUS**	
DATE		**CLASS / CLUSTER**		**WEEK & PERIOD NUMBER**	
CHAPTER & LESSON		**LEARNING OUTCOMES & KPIS:**			

	Time	**Objective**	**KPI No.**	How will you engage students in learning? How will you connect objectives with previous lessons and future topics?	
	10 min **10 min**	Engagement /Focusing Student Attention		**Warm up:** **Recap:**	
HEART OF THE LESSON	**Time**	**Learning Content**		**Teacher Directed Activities:** Are you using a variety of instructional techniques?	**Student Directed Activities:** How will students use technology to gather information, solve problems and work collaboratively?
	15 min	Explanation /Introductory and/or Development al Activities / Lecture			
	Time	**Outcomes in use**		**Extension, Refinement, and Practice Activities:** How will students make connections from content to real-life experiences? How will you give informative feedback?	
	30 min	Elaboration /Independent Activities and/or Meaningful-Use Tasks			
	Time	*Non-stop Assessment*		**Formative Assessment:** How will you follow and track individual progress/learning of students (DIFFERENTIATION)? How will you provide opportunities for students to revise and improve their work based on feedback?	

	25 min	Evaluation /Assessment		
	Time	**Summation**		**Closure Activities:** Through this teacher-guided activity, how will you assist students in reflecting upon what they learned today and preparing for tomorrow's lesson? What homework will be assigned to help students practice, prepare, or elaborate on a concept or skill taught?
		Closure		

RESOURCE PLANNER

Resources Needed	Use of Media & Technology How can the use of technology enhance the learning experience? Are clear handouts prepared?	Cooperative Groupings How will students be involved in group processing? How will students work with one another during the unit?	Writing Opportunities How will students have an opportunity to further extend their thinking through writing?
Hands-On Experiences and/or Manipulative Usage What hands-on experiences and/or manipulative will be used to help students develop an understanding of key skills and processes for investigation?	Differentiation How will you design, adapt and deliver instruction to address each student's diverse learning strengths and needs and create opportunities for students to demonstrate their learning in different ways? How will you ask questions at different levels?	STEAM/21st Century Skills How will you incorporate 21st Century skills and STEAM into this lesson e.g. how will you make connections from content to real life practical applications? What concrete examples will you use? How could you link this lesson to other subjects that the students are studying?	Reflection (at the end of the lesson) What went well? What could be improved for next time? Any resource constraints?