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Factors of STEM Curriculum Integration and Implementation

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ABSTRACT

It is indispensably important that the integrated STEM education in K-12 schools aligns with the 21st-century skills, creates new jobs, improves economies, and educates the next generation of STEM professionals. The STEM Skills Indicator reveals that nine in ten STEM businesses have found it difficult to hire staff with the required skills. The purpose of this study was to examine the key factors impacting the implementation of integrated STEM curriculum in K-12 schools as perceived by teachers. The theoretical framework of the study encompasses two major theories and a model that is appropriate to the integrative nature of this study. The study followed a quantitative research design with a convenience sample of 203 K-12 teachers from both public and private schools in the United Arab Emirates who responded to the developed questionnaire through two delivery modes, online and paper-based. The questionnaire was piloted and contained 44 five-point Likert items, which are categorized into six categories (Assessment, Connection, Curriculum and Delivery, Leadership, Pedagogical Content Knowledge, and Technology and Resources), from related studies, as the components of STEM integration and implementation. Results showed that the 6-factor model had a good fit to the data, with a significant model chi-square, an IFI of 0.572, a TLI of 0.537, a CFI of 0.568, and an RMSEA of 0.120. These results indicated that integration is showcased in cross-disciplinary or interdisciplinary approaches, and that all the factors associated with STEM curriculum integration indicated a positive integration. The Leadership factor has the highest predicted power, followed by Technology and Resources, Assessment, Connection, Pedagogical Content Knowledge, and Curriculum and Delivery. For demographics, only a significant difference was found for teachers' years of experience, with more than two years of experience showing a positive perception of STEM integration and implementation. Based on the results, the discussion and recommendations are provided.

Keywords: STEM education; curriculum integration; curriculum implementation; STEM theoretical framework

INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) education is gaining more focus in educational reform movements today and is funded extensively at both state and national levels (Author, 2022, 2020a; Beckmann & Fervers, 2024; Popova & Zaitseva, 2025). Such educational reform has an intrinsic need of the education system and a crucial pathway to higher-quality, more equitable, and inclusive education (Qu, 2025). However, there appear to be a few standards in place to judge what quality STEM education should look like

(Author, 2019; Hu, 2023; Wang, Moore, Roehrig, & Park, 2011). The lack of research evidence to support STEM education policy for its integration and implementation is evident across the literature, and researchers are struggling to provide this evidence to justify programs and spending at the K-12 schools (Alfarraj & Alzahrani, 2025; Author, 2020a).

Due to the continued interest in STEM topics, numerous in-depth studies have been conducted about different aspects of STEM education. Several studies discussed the essence of STEM education and STEM literacy (Jafaar, Marfazila, Mahmud, Vilbar, & Mohammad, 2025; Bellard, Walker, & Kim, 2017; Gehrke & Kezar, 2017; Ramulumo, 2024). Other studies have addressed students' perceptions toward integrated STEM (James & Singer, 2016; Harris, 2017; Uludüz & Çalik, 2023). In addition, Debes (2018) and Hamilton et al. (2017) investigated the in-service and pre-service teachers' preparation and attitudes toward STEM education. Other researchers, Ernst and Glennie (2015) and Bahrum, Wahid, and Ibrahim (2017), discussed STEM curriculum and the integration of its disciplines, while the authors (2020b) examined an entrepreneurial-STEM model with high school students' experiential learning through competency-based practices.

The rapid change in information and technology, poor performance in math and science by students, different motivation of employees, and the shortage of students going into STEM jobs are related to the STEM education movement as seen in current educational practice (Author 2022). Therefore, many US schools now want to implement STEM curriculum effectively, and many stakeholders push to create and implement STEM curriculum (Allaire, 2017; National Research Council, 2011). In the UK, Yvonne Baker (2020), a chief executive of STEM Learning, stated that 'we are heading towards a perfect storm for STEM businesses in the UK - a very real skills crisis at a time of uncertainty for the economy and as schools are facing unprecedented challenges.' The STEM Skills Indicator reveals that nine in ten (89%) STEM businesses have found it difficult to hire staff with the required skills in the last 12 months, leading to the current shortfall of over 173,000 workers, an average of 10 unfilled roles per business. Locally, some institutes in the UAE have campus-wide STEM initiatives and plans to address the shortage of students with STEM degrees and integrate them to fill STEM jobs in the future (Al-Muhaisin & Khaja, 2015; Author, 2020a). Additionally, STEM education is seen as a way to tackle these gaps in both public and private schools in the country (Pasha-Zaidi & Afari, 2016) and, hence, this study is deemed important in examining the factors impacting STEM curriculum integration in schools and further improve interest in pursuing university degrees in the STEM fields.

Silverman and Clay (2009) conducted a study of self-contained seventh-grade ESL students from an urban setting who were identified as lagging in mathematics to show the benefit of integration during a collaboration of disciplines. It was found that mathematics is more than following procedures; mathematics is a tool to solve and understand real-world problems. Yet, teaching concepts to develop conceptual understanding, problem-solving, reasoning, and mathematical modelling skills, which demand the role of a single-subject learning, such as mathematics, presents a challenge for mathematics teachers to expand their interdisciplinary horizons in STEM learning that emphasizes design-thinking, creativity, and collaboration (Marfuan, 2023). A science teacher commented on the inability of students to calculate percentages and to use math skills in science. According to the report, after collaboration with teachers in social studies, language arts, and intentionally planning to include science and mathematics concepts in an integrated project, achievement improved for most of the seventh graders in mathematics, science, and social studies. Students reported that linking the concepts across disciplines enabled them to develop conceptual understanding rather than memorization.

Till recently the current position of STEM education in many countries relies on the integration between science and mathematics subjects (Zhai, 2019). This shows a lack of true STEM integration, implementation and assessment. Also, other schools make alignment only in the learning outcomes of the four disciplines focusing on project-based learning. The STEM education is also found to be taught as extra-curricular subject or after school activity or as a STEM club in most of schools, as presented in a case study by Sahin, Ayar, and Adiguzel (2014). This is no difference of the challenges face schools and teachers regarding implementation of STEM education in the UAE. According to AlMurshidi (2019), teachers must spend time to prepare for classes and draft lesson plans, grade tests, and other assessment exercises, and also carry out other administrative duties. A lack of formalised training in the teaching methods and tools of STEM education has continued to hamper their deliverables.

Research indicated that students leave STEM fields for a few reasons with the leading attrition factors being lack of motivation, teaching techniques, study skills, rigid course sequencing, poor grades, uninspiring introductory courses, poor advising, and deficiencies in mathematics (Chittum et al. 2017). A lack of student engagement in STEM activities results in low motivation in STEM learning, low academic achievement, and reduced efficacy in the use of metacognitive strategies (Chittum et al. 2017). For these reasons, this study was warranted. Thus, the main purpose of this study was to examine teacher perceptions of the key factors and demographic differences impacting the implementation of integrated STEM curriculum in K-12 schools in the United Arab Emirates. For this study, a general definition of integrated STEM education includes "an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems" (Moore et al., 2014, p.38). Wang et al. (2011) explained that integration can be thought of as a cross-disciplinary approach or sometimes referred to as an interdisciplinary approach. They maintained that "cross-disciplinary" and "interdisciplinary" are familiar educational terms that have been around for many years. Therefore, the present study answered two questions: What are the factors associated with STEM integration and implementation as perceived by K-12 teachers? and, how do demographic variables influence K-12 teachers' perceptions of STEM integration and implementation?

BACKGROUND

Theoretical Framework

The theoretical framework suits the integrative and investigative nature of study. It consists of the Integrative Theory for Drake and Burns (2004), the Socioscientific Issues (SSIs) Theory of science education by Zeidler & Keefer (2003), and the Institutional Theory by DiMaggio and Powell (1991). The Integrative Theory, as proposed by Drake and Burns (2004), indicates that instruction can be organised and taught, from an issue common to the disciplines instead of from a disjointed perspective, in three different integrative approaches: multidisciplinary, transdisciplinary, and interdisciplinary. It suggests that an interdisciplinary approach to STEM education is an efficient and significant way to advance understanding and learning across subject areas. Multidisciplinary integration, which focuses primarily on the disciplines, involves the organisation of curriculum and instruction from two or more disciplines around a particular theme (Drake & Burns 2004). The transdisciplinary integration involves "the organisation of curriculum and instruction around students' questioning, where concepts and skills are developed in real-life context. The transdisciplinary integration is presented in ways such as Understanding by Design, 21st Century Skills and Knowledge, and project and problem-based learning.

The Socioscientific Issues (SSIs) are those open-ended, controversial issues informed by both science and societal factors such as politics, economics, and ethics, which are deliberated by both scientists and the general public (Sadler 2011). The idea of adopting controversial topics such as integrated STEM in teaching has been recognised internationally (Zeidler & Keefer 2003). In a foundational definition, Zeidler and Nicohas (2009) defined SSIs as a movement that incorporated all the goals of STS education while also considering the ethical dimensions of science, the moral reasoning of the child, and the emotional development of the student. The selection of opportunities that enhance students' skills of argumentation, recognition of scientific issues, and evidence-based decision making must necessarily be included and planned carefully. Zeidler (2016) indicated that a sociocultural perspective framed through socioscientific considerations is offered as an alternative conceptualization as well as surplus model to hegemonic STEM practices.

The Institutional Theory by DiMaggio and Powell (1991).DiMaggio and Powell stated that organizations are not solely driven by efficiency and rational choice, but also by social and cultural factors within their environment. It emphasizes how institutions, including rules, norms, and cultural beliefs, shape organizational behavior and lead to isomorphism among organizations within a field. Those transformations require transformation at three levels: student, faculty, and institution (Whittaker & Montgomery 2014). An example of the institutional model is depicted by Rawlings (2011) as a framework design to implement systemic changes in the undergraduate STEM learning and teaching to bolster change in STEM education. According to Rawlings (2011), the model demands for identification of core levels including agents, mechanisms, and structures to sustain it. In this context, the main structure is pedagogy, the varied practices implemented by faculty members to train students, support, and guide their learning. Aligned with calls for a focus on institutional factors, recent efforts of STEM integration require transformation on the institutional level. Educators focus on the ways through which they can make the institutions inclusive for all the learners, including those students having limited English proficiency and categorical disabilities. Referencing the aspect of global development and discovery, the efficiency of STEM education is a vital component cognizant of the welfare and wealth of individuals. STEM education allows learners to be equipped with real-life experience, which prepares them to adapt to life and make informed decisions about work and life in line with augmented technology.

Concept and Challenges of STEM Education

According to Vasquez, Sneider, and Comer (2013) in the book STEM Lesson Essentials, STEM is an interdisciplinary approach to teaching science, technology, engineering, and math through real-world learning experiences. According to Dugger (2010), "[STEM] may be defined as the integration of science, technology, engineering, and mathematics into a new cross-disciplinary subject in schools" (p. 2). This, however, may be an idealised definition because even though some research supports the cross-disciplinary approach as being more relevant and meaningful for students, there appear to be few schools that put this into practice (Alvarez-Vargas et al. 2023; Wang et al. 2011). There is little consensus among practitioners about what STEM education means, and sometimes conflicts exist between the STEM disciplines (Pitt, 2009). Pitt (2009) argued that STEM in an educational context is problematic. For some, STEM education is seen as pre-vocational learning or training that encourages the pursuit of STEM careers. Others view STEM education as a progressive way to learn, where boundaries between subjects tend to blur and students are encouraged to develop transferable knowledge and skills.

Constructivist teachers see themselves as facilitators rather than as transmitters of knowledge (Fortin, Long & Lord 2002). As a result, students who are part of a classroom where teachers are practicing interdisciplinary, constructivist teaching should exhibit a higher degree of understanding of concepts in STEM disciplines and acquire skills in knowledge integration. Additionally, research indicates that constructivist teachers view their students as active participants who create and interpret knowledge (Kim 2024). A more comprehensive perspective on "STEM integration is featured in Vasquez et al.'s work (2013, p.9), Table 1, where different forms of boundary crossing are displayed along a continuum of increasing levels of integration, with progression along the continuum involving greater interconnection and inter-dependence among the disciplines."

Table 1: "Increasing levels of integration (adapted from Vasquez et al. 2013)"

Form of integration	Features
1. "Disciplinary"	"Concepts and skills are learned separately in each discipline"
2. "Multidisciplinary"	"Concepts and skills are learned separately in each discipline but within a common theme"
3. "Interdisciplinary"	"Closely liked concepts and skills are learned from two or more disciplines with the aim of deepening knowledge and skills"
4. "Transdisciplinary"	"Knowledge and skills are learned from two or more disciplines are applied to real-world problems and projects thus helping to shape the learning Experience"

Over the past few years, more and more documents published in the US have shown greater interdisciplinary and transdisciplinary STEM integration. According to the 2014 STEM Task Force Report, for instance, STEM education goes beyond integrating these disciplines for the sake of convenience; such integration includes learning from problems derived from real-world situations and interconnects the four disciplines by way of "cohesive and active teaching and learning approaches" (p.21). Additionally, he stated that "cannot and should not be taught in isolation, just as they do not exist in isolation in the real world or the workforce" (as cited in English 2016, p.9).

Curricular Support Structures for STEM Education

Curricular support structures will be necessary to facilitate the development of an integrated STEM curriculum. The literature identifies many curricular support structures that can improve STEM education when present, or hinder STEM education when not present. These curricular supports in schools are essential to support integrated STEM. The STEM libraries should have important elements, as indicated by Duff (2012), including: highlighting existing STEM resources; emphasising STEM in book orders; providing placement and career training; participating in career fairs; keeping up with technology; speaking to science clubs and student organisations; increasing parent and community involvement; inviting guest speakers; and having book talks (Duff 2012). argues that a major professional competency that librarians should exhibit is supporting cooperation and collaboration. This is borne out in Duff's (2012) exemplary article, 10 Steps to Creating a Cutting-Edge STEM School Library, where the author states that for students to enter STEM career fields, they must first become proficient in STEM classrooms. She argues that access to STEM library and instructional materials is important.

Counselling is another area of traditional student support that can be modified to support STEM education. Schmidt et al. (2012) stated that counsellors affect the career choices of students and are the gatekeepers for STEM coursework. They reported that minority students are underrepresented and often do not believe that STEM courses are relevant to their backgrounds, and that counsellors and other educators need to ensure minority students are exposed to STEM opportunities early in the educational process. Counselling can be an effective support for STEM education as practitioners discuss class choices and career options with students (Jaffar et al, 2025; Schmidt et al. 2012).

Professional development and collaboration for counsellors are essential, and counsellors should improve their willingness/ability to counsel students toward STEM fields for STEM to grow. Counsellors should endeavour to broaden their STEM knowledge base by reviewing theory related to age-appropriate student career development, exploring specific career fields of study, and sharing relevant STEM information with students and parents (Schmidt et al. 2012).

Students develop the skills that will influence STEM-related course selection in high school, and whether they take a STEM-focused program of study or not. Therefore, since counsellors have the power to persuade/dissuade students from STEM fields, professional development is important to inform counsellors about STEM fields and curriculum (Bechman 2024). Strategies to improve counselling for STEM education through professional development include: (a) ensuring that counsellors have access to current career facts and skills requirements for STEM careers; (b) devoting time toward self-evaluation of a counsellor's partiality toward one career area over another; and (c) promoting career linking opportunities (Jafaar, 2025).

METHODOLOGY

The study followed a quantitative approach that was underpinned by the postpositivist philosophy to collect data to answer the study's two main questions, regarding factors of STEM integration and implementation based on K-12 teachers' perceptions and demographics. A convenient sample of 203 K-12 teachers, from both government and private schools in the United Arab Emirates responded to the questionnaire through two delivery modes, online and paper-based. For the ethical considerations and obtaining the appropriate approvals of schools, an email invitation with a covering letter and a link to the online survey was sent to an elected person in each participating school across the five emirates to recruit the participants for data collection.

In developing the questionnaire, the researchers considered content, face, and construct validity. Ideally, content validity, in this case, was completed to affirm that the questionnaire is relevant and appropriate to the purpose of the study. It depicts that the content reflects the attributes investigated in the study and is ascertained by at least six experts (DeVon, Block, Moyle-Wright, Ernst, Hayden, and Lazzara, 2007). In this regard, the research defined the theoretical framework of STEM education and delved into vast literature review as well as seeking opinions from experts. Another ideology addressed was that of face validity where the researchers sought to establish whether the questionnaire is appropriate to the area and purpose of study. In context, this type of validity investigates the readability, feasibility, formatting, and consistency as well as clarity of the lingo, wording, style and layout. Finally, DeVont et al. (2007) ascertain that construct validity focuses on the items that relate to the appropriate theoretical constructs. Here, the final questionnaire contains 44 five-Likert questionnaire items which were categorised into six categories/factors (Assessment, Connection; Curriculum and Delivery, Leadership, Pedagogical Content Knowledge, and Technology and Resources) as the components of STEM integration and implementation. Based on these identified categories, the researchers examined their six hypotheses. Data analysis included descriptive and inferential statistics to examine the significance of these factors on STEM integration and implementation in schools. In this regard, the researchers used IBM SPSS Statistics and IBM SPSS AMOS software to compute descriptive statistics, Pearson correlation, Explanatory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), Structural Equation Modelling (SEM), Analysis of variance (ANOVA), and Multiple Regression Analysis (MLR) to answer the two research questions.

RESULTS

This section presents the results of the two research questions: What factors are associated with STEM integration and implementation as perceived by K-12 teachers? How do demographic variables impact teachers' perceptions of STEM integration and implementation? A representative sample of 203 teachers responded to the online and hardcopy questionnaire to collect the quantitative data for the study. The two sets of analyses were conducted, for both questions, included 5 analyses, first set: A- The inter-item reliabilities were conducted to determine if any study variable demonstrated poor internal consistency and/or showed no significant relationships with other variables, both of which would preclude the need to conduct SEM analysis for the specific variable or sets of variables (Hu & Bentler 1998). B- A comprehensive analysis is provided for the CFA findings of the overall participating teachers' perceptions of the STEM development and implementation. C- Results of the SEM for the hypothesis testing of the six STEM factors. D- A multiple regression analysis is presented to determine the strength of each predictor on perceptions of teachers regarding STEM integration and implementation in schools. Second set: It included: E- the descriptive analyses and results related to question two that investigated how the demographics variables influence participating teachers' perceptions of STEM development and implementation.

Results of Reliability Analysis

For that, the Cronbach score should be more than 0.7. This confirms that the entire teacher questionnaire used in this study is an effective tool and displayed excellent inter-item reliability as indicated by a very high Cronbach's Alpha reliability (0.941). The Cronbach's Alpha reliabilities the for the 6 factors were, as well, acceptable, Assessment 0.79; Connection 0.708; Curriculum and Delivery 0.785; Leadership 0.805 Pedagogical Content Knowledge .867; and Technology& Resources 0.741. After these assumptions are met, it is confirmed that the selected items constitute one factor. For EFA analysis, each item of the category or factor was individually examined for factor loadings on single factor. Each of these items was then loaded into one factor and examine whether their factor loading scores are minimum 0.4. After that, all of the factors were checked for the reliability score again using their items together. The EFA analysis confirmed that all the items are meeting the assumption of loading on the factor and giving the acceptable reliability scores.

Results of the Overall SEM and CFA for Exogenous and Endogenous Latent Constructs of STEM Factors

Structural Equation Modelling (SEM) has become one of the techniques of choice for researchers across disciplines and increasingly is a 'must' for researchers in the social sciences (Yuan, 2005). Statisticians recommend that investigators utilise a two-phase process for SEM models, with the first phase testing measurement models using CFA followed by the second phase testing the structural models using SEM. SEM results will not display good model fit if the latent constructs show poor fit in CFA results (Hu & Bentler 1988). The first step in the analysis of models involved conducting CFAs for exogenous construct of Assessment, Connection, Curriculum and Delivery, Leadership, Pedagogical Content Knowledge, and Technology and Resources factors and the endogenous construct of Perceived Integration and Implementation. In this section of the results, a comprehensive discussion is presented regarding the proposed latent constructs in the study, ending with a presentation of the best latent constructs that emerged from CFA. The CFA assessed the 6-factor model comprised of six latent constructs of STEM questionnaire as shown in Figure 2. Results showed that the 6-factor model had good fit to the data, with a significant model chi-square, an IFI of .572, a TLI of .537, a CFI of .568, and a RMSEA of .120. Chi-square value should be non-significant, for IFI, TLI, and CFI an acceptable output is .50 but the preferred index value should be .6. An acceptable χ 2 /DF is between 2.00 or 3.00 and is indicative of an acceptable fit between the hypothesized model and the actual model. Thus, the χ 2 /DF was within the acceptable range of values, which documented good model fit. RMSEA is a popular measure of fit. Less than .05 indicates good fit, =0.0 indicates exact fit, from .08 to .10 indicates mediocre fit, and greater than .10 indicates poor fit (Hu & Bentler, 1998). Figure 2 below shows the model fit for the 6-factor model comprised of six latent constructs of the STEM questionnaire with their abbreviations which are used throughout the analysis: 1/ Assessment (AS), 2/ Connection (C), 3/ Curriculum and Delivery (CD), 4/ Leadership (L), 5/ Pedagogical Content Knowledge (PCK), and 6/ Technology and Resources (TR).

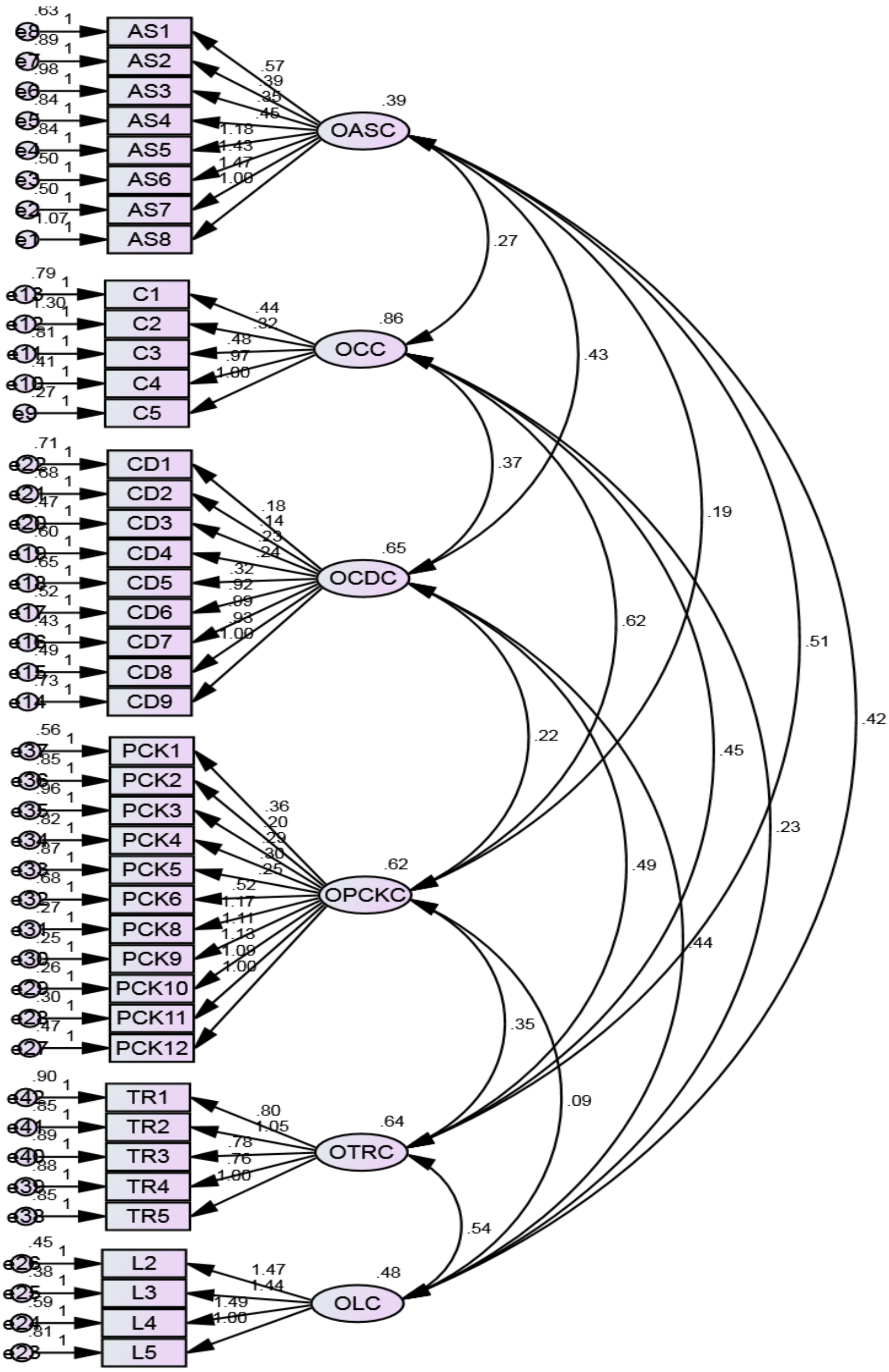

Figure 2: CFA 6- Factor Model Fit Latent Constructs of STEM

Results of the SEM for Hypothesis Testing of the Six STEM Factors

This section presents the results of the SEM models, which were conducted to test the study hypotheses for the six STEM factors of the questionnaire. As stated previously, while SEM models can have an excellent fit, pathways in the model can be non-significant (Hu & Bentler 1998). Therefore, in the following sections, a table of model results precedes the SEM model. The tables provide information on model variables' respective pathways, estimates, SE, CR, and P values.

Results of Hypothesis 1: Assessment

The first hypothesis was that the latent construct of Assessment factor would predict perceived STEM implementation and integration of teachers, an observed variable. To test this hypothesis, SEM was conducted to compute relationships between unobserved constructs (latent variables) from observable variables, and results from the SEM are shown in Figure 3. The assessment factor latent construct significantly predicts perceived STEM implementation and integration of teachers across all the individual statements. Assessment predicts around 89% of teachers' perceived STEM implementation and integration. This means that participants perceived that integrating Assessment in STEM is effective for STEM implementation and integration in schools.

All the sub-factors of the Assessment factor are statistically significant. However, the most significant sub-factors are AS8, AS7, AS6, and AS5. These sub-factors explain teachers' perceptions of having a clear STEM assessment policy for the assessment of students. This means that participants perceived that integrating STEM assessment policy within the Assessment factor is effective for STEM implementation and integration in schools. Based on the significance of the results, Hypothesis 1 was supported as follows: As a teacher, I believe that I can develop different kinds of assessments to measure students' integrated knowledge of STEM at the end of an instructional unit (AS8). STEM assessment policy in my organisation has a clear structure for both summative and formative assessments (AS7). STEM assessment policy in my organisation has a clear structure for formative assessments only (AS6). STEM assessment policy in my organisation has a clear structure for summative assessment only (AS5).

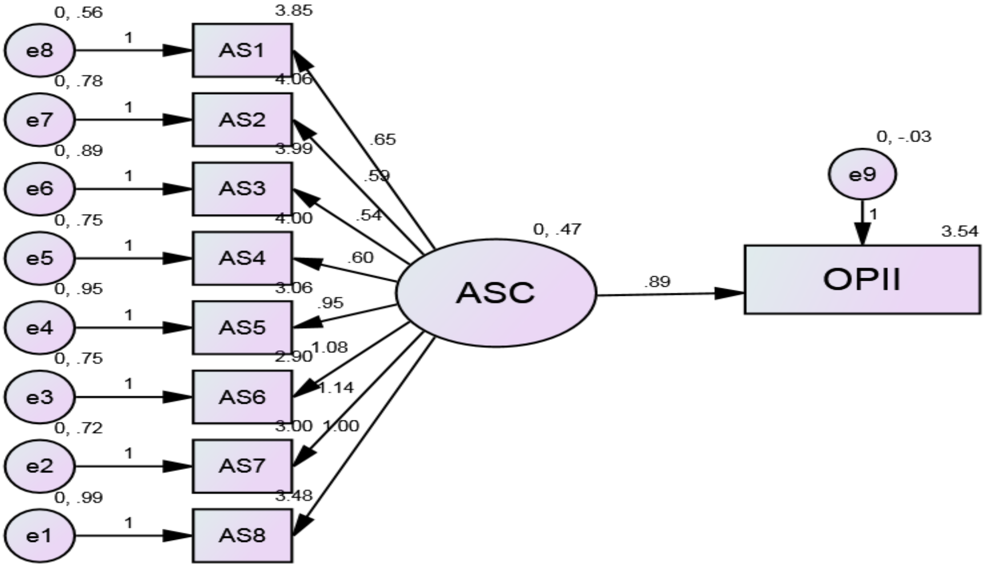

Figure 3: SEM model for Hypothesis 1: Assessment factors predicting Overall Perceived STEM Implementation and Integration of Teachers

Results for Hypothesis 2: Connection

The second hypothesis was that the latent construct of Connection factors would predict perceived STEM implementation and integration of teachers, an observed variable. For testing this hypothesis, the Structural Equation Modelling (SEM) was conducted to impute relationships between unobserved constructs (latent variables) from observable variables, as shown in Figure 4. The connection factor latent construct significantly predicts perceived STEM implementation and integration of teachers across all the individual statements. Connection predicts around 100% of teachers' perceived STEM implementation and integration. Based on the significance of the results, Hypothesis 2 was supported. This means that participants perceived that integrating connection in STEM is effective for STEM implementation and integration in the participating schools. This suggests that STEM should not be bound to be only theory based but it should connect with some form of practice. All the connection sub-factors are statistically significant. However, the most significant sub-factors among them are: C2, C4, and C3. These sub-factors mostly explain teachers' perceptions of connecting STEM subjects with the practical world by integrating the industries/businesses, latest technologies, and innovation and entrepreneurship so that teachers and students can take advantage of STEM integration and implementation. The figure presents the results of these significant hypotheses, respectively. Business and industry partners are involved with STEM education in my organization (C2). As a teacher, I believe that I can connect concepts to those of engineering, science, and technology (C4). My organisation promotes a culture of innovation and entrepreneurship in STEM field amongst students (C3).

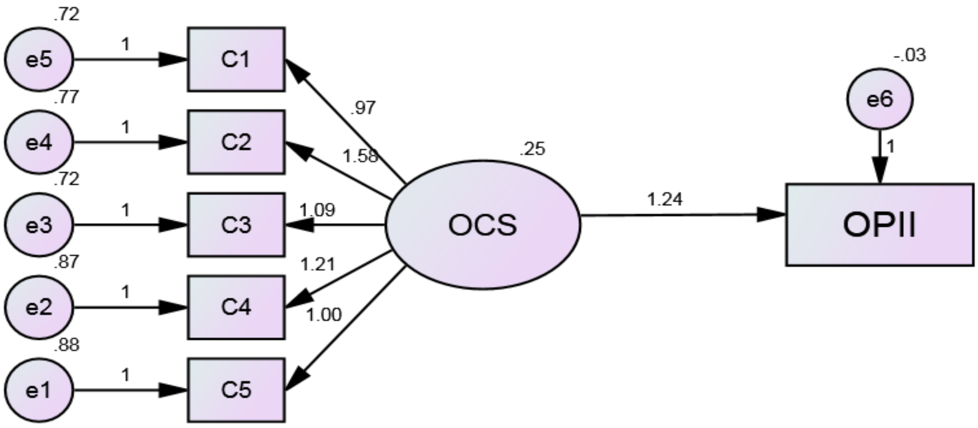

Figure 4: SEM model for Hypothesis 2: Connection factors predicting Overall Perceived STEM Implementation and Integration of Teachers

Results for Hypothesis 3: Curriculum and Delivery

The third hypothesis was that the latent construct of Curriculum and Delivery factors would predict perceived STEM implementation and integration of teachers, an observed variable. To test this hypothesis, SEM was conducted, to impute relationships between unobserved constructs (latent variables) from observable variables and results from the SEM are shown in Figure 5. The curriculum and delivery factor latent construct significantly predict perceived STEM implementation and integration of teachers across all the individual statements (70%). Based on the significance of the results, Hypothesis 3 was supported. This means that participants perceived that integrating curriculum and delivery in STEM is effective for STEM implementation and integration in schools.

All the sub-factors of curriculum and delivery factor are statistically significant. However, the most significant sub-factors are ranked as: CD9, CD8, CD7, and CD6. These sub-factors mostly explain the perceptions of teachers related to giving equal emphasis regarding content of each four subjects of STEM and having transdisciplinary, interdisciplinary, and multi-disciplinary instruction models. This suggests that STEM curriculum and delivery should be holistic where each subject should be given equal emphasis around transdisciplinary, interdisciplinary and multi-disciplinary instructional models. In particular, the accepted hypotheses are significant and ranked as: A STEM class or course in my organisation has equal emphasis regarding content (instruction) in the four disciplines/areas (CD9). STEM curriculum in my organisation is transdisciplinary (Knowledge and skills learned from two or more disciplines are applied to real-world problems and projects, thus helping to shape the learning experience) (CD8). STEM curriculum in my organisation is interdisciplinary (Closely linked concepts and skills are learned from two or more disciplines with the aim of deepening knowledge and skills) (CD7). STEM curriculum in my organisation is a multi-disciplinary (Concepts and skills are learned separately in each discipline but within a common theme) (CD6).

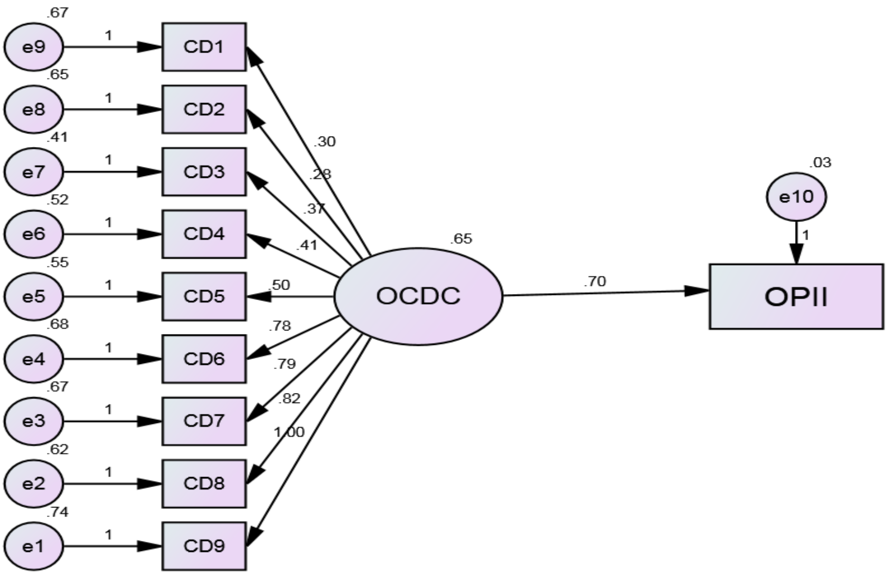

Figure 5: SEM model for Hypothesis 3: Curriculum and Delivery factors predicting Overall Perceived STEM Implementation and Integration of Teachers

Results for Hypothesis 4: Leadership

The fourth hypothesis was that the latent construct of Leadership factors would predict perceived STEM implementation and integration of teachers, an observed variable. To test this hypothesis, SEM was conducted, to find the relationships between unobserved constructs (latent variables) from observable variables and results from the SEM are shown in Figure 6. The leadership factor latent construct significantly predicts perceived STEM implementation and integration of teachers across all the individual statements (69%). This means that participants perceived that integrating leadership in STEM is effective for STEM implementation and integration in schools. Based on the significance of the results, Hypothesis 4 was supported. All the sub-factors of leadership factor are statistically significant. There out of four sub-factors were significant and ranked as: L4, L3, and L2. These sub-factors explain the perceptions of teachers related to collaboration and professional development opportunities of collaborating with other teachers to learn about the best assessment strategies in STEM. This suggests that STEM leadership, through collaboration and professional development, is very important for teachers' self-efficacy and confidence in teaching the STEM content and achieving the desired achievement levels of their students. The significant sub-factors are: STEM teachers collaborate often to reflect on student work (L4). We received appropriate PD on best assessment strategies in the STEM field (L3). Professional development opportunities around STEM are regularly provided to teachers in my organisation (L2).

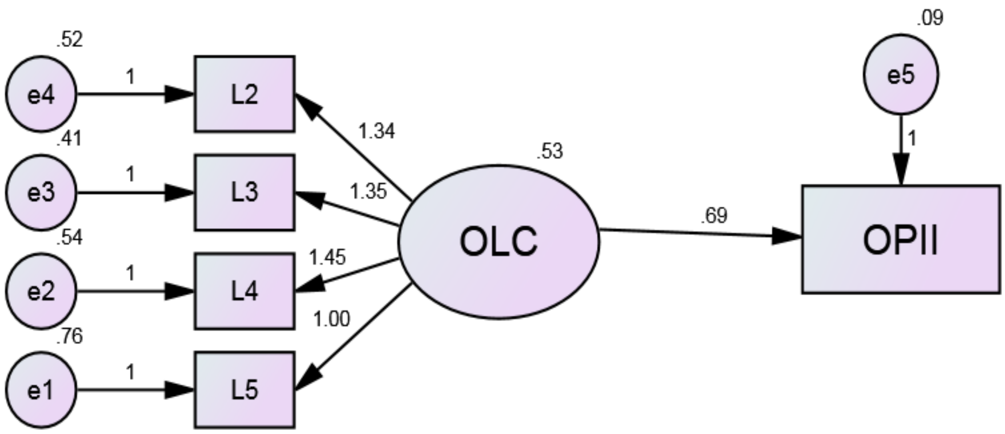

Figure 6: SEM model for Hypothesis 4: Leadership factors predicting Overall Perceived STEM Implementation and Integration of Teachers

Results for Hypothesis 5: Pedagogical Content Knowledge

The fifth hypothesis was that the latent construct of Pedagogical Content Knowledge factors would predict perceived STEM implementation and integration of teachers, an observed variable. To test this hypothesis, SEM was conducted, to impute relationships between unobserved constructs (latent variables) from observable variables and results from the SEM are shown in Figure 7. The pedagogical content knowledge factor latent construct significantly predicts perceived STEM implementation and integration of teachers across all the individual statements (44%). This means that participants perceived that integrating pedagogy and content knowledge in STEM is effective for STEM implementation and integration in UAE schools. All the sub-factors of pedagogical content knowledge factor are statistically significant. However, the most significant sub-factors among them are: PCK 10, PCK 8, PCK 9, and PCK 11. These sub-factors mostly explain the perceptions of teachers related to learning about new teaching strategies, gaining teaching skills, learning new technologies, adapting new teaching situations, and inspiring students which are believed to be important by participating teachers for their pedagogical content knowledge and are significant in STEM implementation and integration for schools. Based on the significance of the results, Hypothesis 5 was supported and sub-factors are ranked as: As a teacher, I believe that I can learn new technologies that will enable me to teach from within an integrated STEM framework (PCK10). As a teacher, I believe that I can develop new knowledge and skills necessary to teach subjects from within an integrated STEM framework (PCK8). As a teacher, I believe that I can adapt to new teaching situations such as those necessary to teach subjects from within an integrated STEM framework (PCK9). As a teacher, I believe that I can get students to experience excitement, interest, and motivation to learn about science, technology, engineering and mathematics connection to the real world (PCK11).

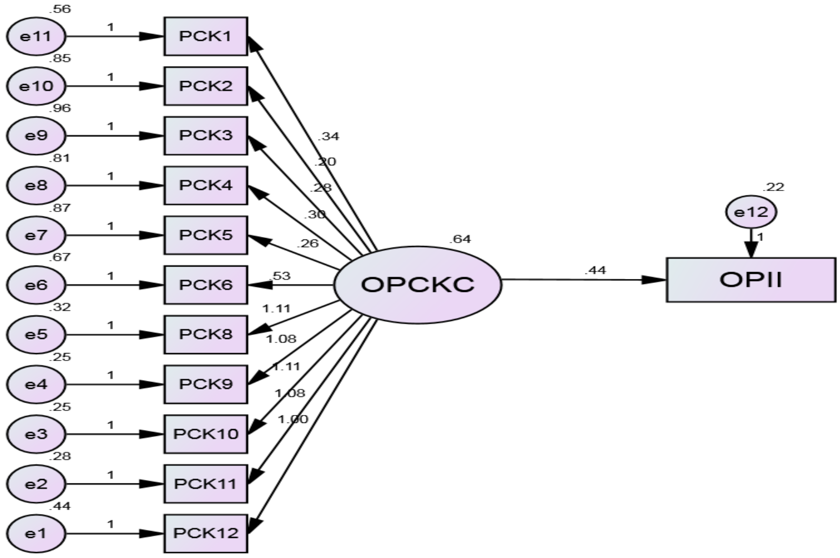

Figure 7: SEM model for Hypothesis 5: Pedagogical Content Knowledge factors predicting Overall Perceived STEM Implementation and Integration of Teachers

Results for Hypothesis 6: Technology and Resources

The sixth hypothesis was that the latent construct of Technology and Resources factors would predict perceived STEM implementation and integration of teachers, an observed variable. To test this hypothesis, SEM was conducted, to calculate relationships between unobserved constructs (latent variables) from observable variables and results from the SEM are shown in Figure 8. The technology and resources factor latent construct significantly predict perceived STEM implementation and integration of teachers across all the individual statements. This means that participants perceived that integrating technology and resources in STEM is effective for STEM implementation and integration in UAE schools. Three of the four sub-factors of technology and resources factor are found to be statistically significant and ranked as: TR2, TR3, and TR5. These sub-factors mostly explain the perceptions of teachers related to equipment, facilities, resources, technology, and supporting materials which teachers believe are important for delivering the STEM content and curriculum and are significant in STEM implementation and integration in UAE schools. The importance of technology and resources factor also implies that teachers would be effective in teaching and integrating STEM in virtual or distance learning environment. Based on the significance of the results, Hypothesis 6 was supported, and its significant sub-factors are ranked as follows: Equipment, facilities, and resources are available in the classroom or at the college site to meet STEM education goals, objectives, or standards (TR2). Technology is used throughout my STEM program as a tool to facilitate research (TR3). As a teacher, I believe that I can obtain the materials necessary to teach mathematics through STEM in an integrated way (TR5).

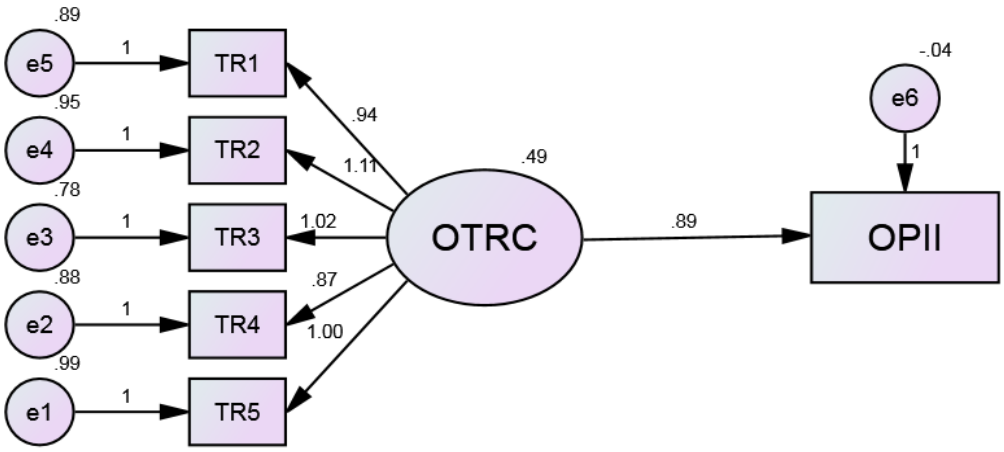

Figure 8: SEM model for Hypothesis 6: Technology and Resources factors predicting Overall Perceived STEM Implementation and Integration of Teachers

Results of the Multiple Regression Analysis

For measuring the impact of each factor on the overall STEM integration and implementation based on teacher questionnaire responses, a composite variable of perceived STEM implementation and integration of teachers is computed using ANOVA, Table 2. The results show model fit at statistically significant level (F(6, 196) = 1329.144, p < .05) and indicates that regression coefficients can be examined for most significant independent variables measuring dependent variable as presented in Table 4 shows the findings of multiple regression analysis where Composite Variable of perceived STEM implementation and integration of teachers is dependent variable and construct of Assessment, Connection, Curriculum and Delivery, Leadership, Pedagogical Content Knowledge, and Technology and Resources factors are independent variables. The findings indicated that all the predictors are significant with perceived STEM implementation and integration of teachers. The results indicated that there is positive and significant relationship between perceived effectiveness of Assessment, Connection, Curriculum and Delivery, Leadership, Pedagogical Content Knowledge, and Technology and Resources with perceived STEM implementation and integration of teachers. This suggests as well as confirms the CFA and SEM results. Among all these predictors, leadership has the highest prediction power (25.3%). Followed by Technology and Resources (19.2%), Assessment (15.8%), Connection and Pedagogical Content Knowledge (14.1%), and, lastly, Curriculum and Delivery (11.5%). These findings indicated that teachers give highest importance to leadership, technology and resources, and assessment as the most significant factors associated with STEM integration and implementation in schools.

Table 2: Regression Coefficients of Factors Associated with STEM Integration and Implementation

Coefficients[a]							
Model		Unstandardized Coefficients		Standardised Coefficients		t	Sig.
		B	Std. Error	Beta	Contribution to Model*		
1	(Constant)	-11.000	.348			-31.648	.000
	OAS	1.189	.150	.184	15.8%	7.923	.000
	OC	.947	.103	.165	14.1%	9.177	.000
	OCD	1.028	.143	.134	11.5%	7.210	.000
	OL	1.419	.107	.295	25.3%	13.280	.000
	OPCK	1.151	.136	.165	14.1%	8.437	.000
	OTR	1.145	.108	.224	19.2%	10.579	.000
a. Dependent Variable: OPII *Computed by Researcher							

OAS = Overall Assessment**; OC =** Overall Connection**; OCD =** Overall Curriculum and Delivery**; OL =** Overall Leadership**; OPCK =** Overall Pedagogical Content Knowledge**; OTR =** Overall Technology and Resources**.** **. Significant at the 0.05 level

Results of Demographic Descriptive Statistics

Normality is examined earlier for the SEM analyses, and all variables were higher than 0.8. The following results presented the T-test results (when comparing 2 groups) and one-way ANOVA results (when comparing more than 2 groups) for these 6 categories/components of STEM integration and implementation. The researcher analysed if there were differences in teachers' overall perceptions about STEM implementation and integration between their demographic characteristics.

Table 3 shows the t-test results of Teachers' Gender (Male and Female) and Seven STEM Factors. The findings indicated that there are no statistically significant differences in male and female teachers towards their perceptions regarding assessment, curriculum and delivery, leadership, pedagogical content knowledge, technology and resources and overall perceived integration and implementation. However, there is statistically significant difference in male and female teachers towards their perceptions regarding Connection (Sig = 0.019, p < 0.05). This means that male teachers (Mean = 3.6981) have slightly more positive attitudes towards Connection compared to female teachers (Mean = 3.4418) in the participating schools.

Table 3: T-test Results of Teachers' Gender and STEM Factors

	Gender	**N**	**Mean**	**Sig**
OAS	Male	104	3.63	0.343
	Female	91	3.43	
OC	Male	104	3.69	0.019**
	Female	91	3.44	
OCD	Male	104	3.85	0.303
	Female	91	3.68	

OL	Male	104	3.35	0.292
	Female	91	3.03	
OPCK	Male	104	3.90	0.117
	Female	91	3.75	
OTR	Male	104	3.48	0.383
	Female	91	3.14	
OPII	Male	104	13.96	0.419
	Female	91	12.47	

OAS = Overall Assessment**; OC =** Overall Connection**; OCD =** Overall Curriculum and Delivery**; OL =** Overall Leadership**; OPCK =** Overall Pedagogical Content Knowledge**; OTR =** Overall Technology and Resources**; OPII =** Overall Perceived Integration and Implementation

**. Significant at the 0.05 level

Table 4 shows the one-way ANOVA results of Teachers' Degree Major and seven STEM Factors. The findings indicated that there are no statistically significant differences among teachers with different degree majors towards their perception regarding Assessment, Connection, Curriculum and Delivery, Leadership, and Pedagogical Content Knowledge. However, there are statistically significant differences in teachers with different degree majors towards their perception regarding Technology and resources (Sig =0.016, $p < 0.05$). It is indicated that teachers with mathematics degree majors (3.55) followed by teachers with science degree majors (3.47) and teachers with Education degree majors (3.39) have more positive attitudes than teachers with degree majors of computer science, engineering, and others.

Table 4: One-way ANOVA Results of Teachers' Degree Major and STEM Factors

		Computer Science	Education	Engineering	Maths	Science	Others	Total
	N	34	48	21	36	47	16	202
OAS	Mean	3.38	3.60	3.42	3.64	3.58	3.54	3.54
	Sig	0.503						
OC	Mean	3.51	3.65	3.34	3.62	3.634	3.45	3.57
	Sig	0.554						
OCD	Mean	3.66	3.81	3.76	3.88	3.74	3.70	3.76
	Sig	0.592						
OL	Mean	2.84	3.29	2.96	3.25	3.36	3.33	3.19
	Sig	0.068						
OPCK	Mean	3.69	3.86	3.78	3.95	3.84	3.82	3.83
	Sig	0.579						
OTR	Mean	3.02	3.39	2.96	3.55	3.47	3.27	3.32
	Sig	0.016**						
OPII	Mean	11.85	13.58	12.29	13.97	13.75	13.21	13.23
	Sig	0.222						

Table 5 shows the one-way ANOVA results of Teachers' Instructional Grade Level and Seven STEM Factors. The findings indicated that there are no statistically significant differences among teachers teaching at different instruction level towards their perception regarding Assessment, Connection, Curriculum and Delivery, Leadership, and Technology and resources. However, there are statistically significant differences in teachers teaching at different instruction level towards their perception regarding Pedagogical Content Knowledge (Sig =0.013, $p < 0.05$), It is indicated that teachers teaching at primary school (3.94) followed by teachers teaching at high school (3.85) and teachers teaching at middle school (3.84) have more positive attitudes than teachers teaching at kindergarten.

Table 5: One-way ANOVA Results of Teachers' Instructional Grade Level and STEM Factors

		High School	**Kindergarten**	**Middle School**	**Primary School**	**Total**
	N	**121**	**7**	**50**	**16**	**194**
OAS	Mean	3.61	3.10	3.47	3.30	3.53
	Sig	0.065				
OC	Mean	3.59	3.28	3.52	3.63	3.57
	Sig	0.674				
OCD	Mean	3.79	3.41	3.74	3.79	3.76
	Sig	0.334				
OL	Mean	3.29	3.22	3.10	2.76	3.19
	Sig	0.104				
OPCK	Mean	3.85	3.11	3.84	3.94	3.83
	Sig	0.013**				
OTR	Mean	3.40	3.08	3.25	2.96	3.31
	Sig	0.146				
OPII	Mean	13.62	11.07	12.80	12.24	13.20
	Sig	0.218				

Table 6 shows the one-way ANOVA results of Teachers' Years of Teaching Experience and Seven STEM Factors. The findings indicated that there are no statistically significant differences among teachers with different teaching experience towards their perception regarding Connection, Curriculum and Delivery, Pedagogical Content Knowledge and Technology and resources. However, there are statistically significant differences among teachers with different teaching experience towards their perception regarding Assessment (Sig =0.016, $p < 0.05$) and Leadership (Sig =0.018, $p < 0.05$). It is indicated that teachers with more than 2 years of teaching experience (3.64) followed by teachers with 2 years of experience (3.35) have more positive attitudes regarding integration of assessment in STEM than teachers with 1 year of teaching experience. Similarly, the results showed that teachers with more than 2 years of teaching experience (3.33) followed by teachers with 1 year of experience (3.03) have more positive attitudes regarding integration of leadership in STEM than teachers with 2 years of teaching experience.

Table 6: One-way ANOVA Results of Teachers' Years of Teaching Experience and STEM Factors

		1 Year	**2 Years**	**More than 2 Years**	**Total**
	N	**31**	**40**	**128**	**199**
OAS	Mean	3.39	3.35	3.64	3.54
	Sig	0.016**			
OC	Mean	3.50	3.44	3.63	3.57
	Sig	0.276			
OCD	Mean	3.65	3.67	3.83	3.77
	Sig	0.101			
OL	Mean	3.03	2.94	3.33	3.20
	Sig	0.018**			
OPCK	Mean	3.66	3.89	3.86	3.84
	Sig	0.21			
OTR	Mean	3.19	3.15	3.42	3.33
	Sig	0.117			
OPII	Mean	12.27	12.20	13.86	13.28
	Sig	0.03**			

The summary of the descriptive findings indicated that apparently there are no major differences for the overall STEM integration and implementation teacher perceptions based on gender, degree major, and instructional grade level. The only overall significant difference is found for Years of Teaching Experience. The study suggests that high school teachers are the ones with substantive experience in STEM. Mostly teachers with more than 2 years of experience have positive perceptions about STEM implementation and integration. The findings also indicated that teachers with Mathematics, Science, and Education degree majors have more positive perceptions than those with degree majors of computer science, engineering, and others. Furthermore, the teachers at the primary schools, high schools, and middle schools have more positive attitudes than those at kindergarten. Moreover, the findings also indicated that male teachers have slightly more positive attitudes compared to female teachers in schools. In addition, significant findings for the STEM different factors based on some demographics are found, such as teachers with more than two years of teaching experience, math, science and technology teachers regarding Technology & Resources, teachers with more than 2 years regarding Assessment and Leadership factors. Overall, the participating teachers have reported most positive attitudes towards integration of Pedagogical Content Knowledge and Curriculum and Delivery factors.

DISCUSSION

This section discusses and interprets both inferential and descriptive results of the two research questions considering previous research studies and the theoretical framework. The first research question was to measure the factors associated with STEM integration and implementation as perceived by K-12 teachers. The findings indicated that the six factors, Assessment, Connection, Curriculum and Delivery, Leadership, Pedagogical Content Knowledge, and Technology and Resources, were significantly associated with STEM integration and implementation in schools. The SEM results indicated that all these factors are significantly associated with STEM integration and implementation. These findings are supported by our earlier studies (Author, 2020a; 2019). Also, are supported by Rawlings' model (2011) which included agents and structures that necessarily to develop appropriate STEM curriculum, such as pedagogy, assessment, resources and technology. Then, were further examined by use of Multiple Regression Analysis to indicate which among these factors are highly significant. The findings indicated that teachers gave highest importance to leadership, technology and resources, and assessment as the most significant factors associated with STEM integration and implementation in the participating schools, similarly to studies by Author 2022; Kelley and Knowles (2016); Ramulumo 2024; Popova & Zaitseva 2025).

As mentioned earlier, there is a rise in interest related to providing students with learning that makes connections across STEM disciplines worldwide (Zhai, 2019); however, there is little research and/or consensus on what integrated STEM means and how to create integrated STEM offerings for student learning (NAE, 2014). The present study identified key factors that can be used to springboard and develop meaningful STEM education experience. Additionally, Drake and Burns's theory (2004) and Bin Idris and Govindasamy (2023), supported these findings that there is a need for clarity in the STEM integration outcomes that may be expected, and the arrangement of developmental sequences related to the curriculum. Similarly, that was first though in the earlier stages of the STEM education development that there are few organised efforts that include engineering experiences in high school STEM classes. According to the National Academy of Engineering and National Research Council report, STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research, there is little research on how to best conduct integrated STEM, or what factors make the integration of STEM subjects increase student learning, interest, retention, achievement, or other outcomes (NAE, 2014).

The NRC report, "Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics" (2011), identified another critical component of integrated STEM education, which is adequate instructional time. The NRC report states that the No Child Left Behind (NCLB) legislation has changed the time allotted for science, technology, engineering, mathematics teaching, and learning in the K-12 curriculums. The findings of the present study identified resources as an important factor for STEM integration. Yet, the K-12 schools, based on the NCLB policy, focus more on mathematics and English because these subjects are tested annually at the expense of losing time for science, technology, and engineering education (Alvares-Vargas, 2023). This decrease in educational time for science education is a problem, not only in providing inadequate instruction (Author 2022) but also in decreasing interest in science and STEM careers (NRC, 2011) and the inequality opportunities for students (Uludüz & Çalik, 2023). Therefore, this may directly affect the teacher's ability to instruct quality integrated STEM which in direct connection to Whittaker and Montgomery's (2014) Institutional Theory as presented as part of the theoretical framework of the study.

Equal access to high-quality STEM learning opportunities was cited as another critical component for integrated STEM curriculum in the literature and the theoretical framework, in particular Drake and Burn's (2004) models of Integrative Theory. These learning opportunities must have an inclusive STEM mission, where goals are stated clearly to prepare students for STEM careers, to support students from minority and underrepresented population groups, and to have an emphasis on recruiting students from these underrepresented population groups (NRC, 2011; Stone et al. 2017). These opportunities allow students to connect with businesses, industry, and the world of work via internships, mentorships, and projects, both within the school day and outside the school day/school year. This confirms Zeidler's (2016) findings that indicated a sociocultural perspective framed through socioscientific considerations offers an alternative conceptualization as well as surplus model to hegemonic STEM practices. These research experiences provide hands-on experience for students and have the possibility of increasing interest in STEM career fields (Author, 2020b; Buckley, et al, 2019; Kim 2024). The importance of this category was clearly defined in the participants' questionnaire responses that these types of experiences for students are essential for STEM integration and implementation. Technology and Resources is indicated among top three major factors influencing such integration and implementation of STEM education. An earlier study by AlMurshidi (2019) found the lack of resources and model of integration to be considered as main obstacles of STEM education integration and development in the UAE. Also, collaboration among teachers of all disciplines was seen as a critical integrated STEM component. Teachers from all disciplines should meet to analyse lesson plans and student work, to improve future learning (Author, 2020b). STEM education requires collaboration, since teachers have not been trained in all STEM curricular areas.

Professional development/teacher support was another key component of integrated STEM education identified in the literature. According to the National Academy of Engineering (2014), very few teacher education programs are preparing prospective teachers with appropriate knowledge in more than one STEM curricular area. With the increase the presence of engineering in the K-12 classroom, teachers must be exposed to training on engineering concepts, and how to integrate those concepts into the classroom (Montgomery & Fernández-Cárdenas, 2018). Professional development of teachers allows them to become more comfortable with their own knowledge of STEM, and as teachers learn more about math and science they become more comfortable teaching STEM (Debes, 2018). The implementation of integrated STEM education in all educational settings will require additional content and pedagogical knowledge beyond which teachers currently are trained (Author, 2020a; Marfuah & Khikmawatib, 2023), therefore schools, presently attempting to have an integrated STEM curriculum must provide professional development for its teachers and leaders (Afarraj & Alzahrani, 2025; James & Singer, 2016; NAE, 2014).

The study revealed no significant differences in overall STEM integration and implementation teacher perceptions based on gender, degree major, and instructional grade level. The only overall significant difference is found for Years of Teaching Experience. Mostly, teachers with more than two years of experience have positive perceptions about STEM education. The findings also indicated some positive perceptions with high means for, e.g., high school teachers are found to be the ones with substantive experience in STEM than those in elementary and missile school levels. These results are supported by similar findings of our previous studies (Author, 2020; 2022) and Jafaar's et al. (2025). Also, teachers with Mathematics, Science, and Education degree majors have more positive perceptions than those with degree majors of computer science, engineering, and others.

CONCLUSION AND RECOMMENDATIONS

In conclusion, the main purpose of this study was to examine the key factors as perceived by teachers and their demographic variables as they relate to the implementation of an integrated STEM curriculum in K-12 schools. The main results indicated statistically significant differences for six factors, Assessment, Connection, Curriculum and Delivery, Leadership, Pedagogical Content Knowledge, and Technology of the STEM integration and implementation. Yet, the Leadership factor has the highest predicted power, followed by Technology and Resources; Assessment; Connection; Pedagogical Content Knowledge; and Curriculum and Delivery. Teacher perceptions based on the demographics of gender, degree major, and instructional grade level did not show significant differences. Only demographic variables of years of teaching did that teaches with 2 years of experience and more indicated positive perception of STEM curriculum integration and implementation. The study is a direct contribution to the foremost international attention recently given to K-12 STEM education, which is becoming a major catalyst of educational reform in many developing counties. It is imperative to inform policy makers, educators, and teachers on the factors, policies, and implementation concerning integrated K12 STEM education.

Several recommendations can be drawn from the findings and discussion of this research study. A policy recommendation for an appropriate contextual framework or model needs to be developed for educators and policy makers to better implementation STEM education. Schools should encourage and support STEM programs at the K-12 level. Business and industry leaders, as well as universities, should become more invested in assisting K-12 schools with teacher training and resources to better impact student STEM learning and career preparation. Teachers will benefit from the factors identified in this study to provide authentic experiences to students via well-planned, integrated STEM experiences. There is a pressing need for a supportive system of assessment and accountability for the integrated STEM. Also, school districts should provide apprenticeship opportunities for STEM teachers to work with scientists or engineers. Continuous professional development will aid teachers in accessing up-to-date STEM resources, collaborating to share best practices, and better assessing their students.

Further research investigations can be conducted in similar contexts with a larger sample, student focus, and policy development.

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