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Transdisciplinary STEAM Curriculum Design and Authentic Assessment in Online Learning: A Model of Cognitive, Psychomotor, and Affective Domains

Areej ElSayary[1]

[1]*Assistant Professor, Education Studies, Zayed University, Abu Dhabi, United Arab Emirates*
Areej.elsayary@zu.ac.ae, https://orcid.org/0000-0002-5554-0069

ABSTRACT
This study investigates teachers' perceptions and practices of designing and teaching transdisciplinary STEAM curriculum using online authentic assessment. Aligning the transdisciplinary STEAM curriculum to authentic assessment is a conceptual framework that guided this study to focus on the three learning domains (cognitive, psychomotor, and affective). The participants are middle and high school teachers (n = 37) in a private school in the United Arab Emirates (UAE). An exploratory mixed method was adopted as a research design. The qualitative data (document analysis) was gathered through analyzing STEAM lesson plans. An online questionnaire was used to collect the quantitative data from teachers. The study's results reveal that teachers' perceptions and practices about the design of STEAM curriculum using authentic assessment were positive with regards to the three learning domains (cognitive, psychomotor, and affective). The highest agreement of teachers' responses was found to be in the affective domain.

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Introduction

Science, Technology, Engineering, and Mathematics (STEM) education is a unique approach of teaching and learning that centers around students' learning and interests. STEM refers to integrating scientific subjects, while STEAM refers to integrating scientific and non-scientific subjects. The novelty in each of the fields is as follows:

- In science, it is in hands-on learning.
- In technology, it is in the projects.
- In engineering, it is in the design planning.
- In art, it is in the creative products.
- In mathematics, it is in the prominent use of modeling (Drake & Reid, 2017).

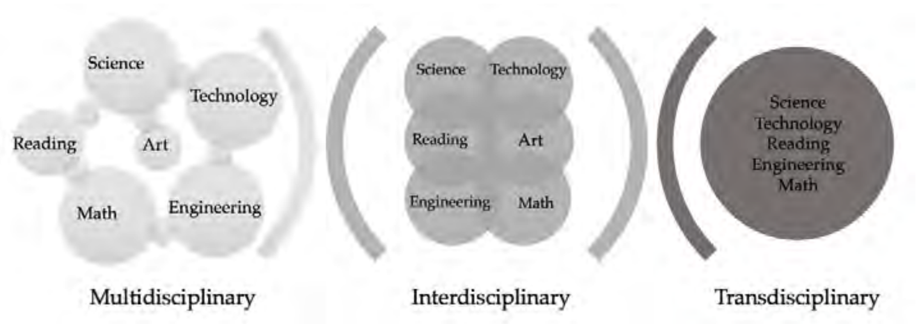
According to Yakman (2010), the A in STEAM indicates the design arts and the arts of language, history, psychology, and sociology. STEM and the arts have opposite, complementary characteristics. The STEM disciplines are objective, logical, analytical, and reproducible, while the arts are subjective, intuitive, sensual, unique, and frivolous (Sousa & Pilecki, 2013). STEM focuses on convergent skills; however, art focuses on divergent skills (Land, 2013). Accordingly, the shift from STEM to STEAM highlights the transition from convergent to divergent thinking which enables students to reach higher levels of creativity (Gettings, 2017) causing changes in students' habits of mind (Taylor, 2017). In UAE, the inclusion of art and reading within STEM took place in governmental schools, institutes, and colleges to form STEAM and STrEAM (Moonsear et al., 2015). In this research, the focus of art is on design arts and language arts.

STEM is considered to be a new educational reform in the UAE (Al Sawaleh, 2017). Due to the massive shortage of qualified high-tech workers, countries of the Gulf Council (GCC) have experienced a global shift toward a knowledge-based economy in the 21st century through the movement from the oil dependence toward the promotion of science, technology, business, tourism, and other sectors (UAE Government, 2015). UAE Vision 2021, Advanced Sciences Agenda, National Innovation Strategy, and the Fourth Industrial Revolution Strategy promote STEM through educational reform and strategic measures.

The transdisciplinary curriculum is a complex integration of multiple subjects where the boundaries among them are blurred (Drake & Reid, 2017) to focus on a real-life problem (Tan & Leong, 2014). Ellis (2009) and Holley (2009) distinguished three types of integration: multidisciplinary, interdisciplinary, and transdisciplinary. Figure 1 represents the degree of integration among subjects graphically. Multidisciplinary integration is the lowest degree of integration between two or among more disciplines in which the topic is explained from the perspectives of different disciplines (Dugger & Fellow, 2011; Repko, 2008). Interdisciplinary integration involves more integration among the subjects and depends mainly on the discipline to solve complex problems (Drake, 1991; Repko, 2008). Transdisciplinary integration is the most robust type of integration of knowledge, skills, and attitudes. It involves the overlap of disciplinary boundaries integrated under one subject to represent a problem (Repko, 2008). Regardless the degree or type of integration, it is important to understand the different types of designing and planning the curriculum.

Figure 1

Different types of STrEAM integration



Note. (Dugger & Fellow (2011) and Repko (2008))

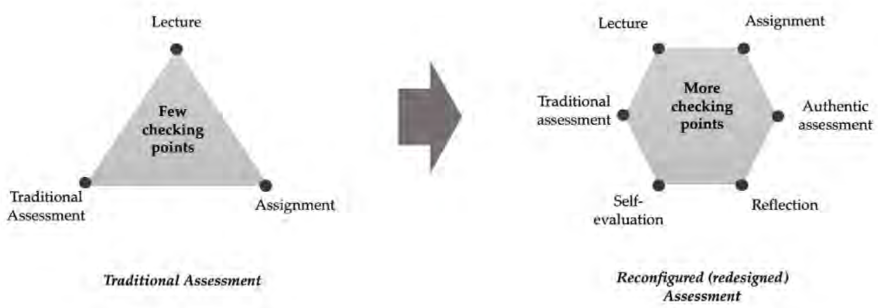
Curriculum designers need to consider the end (desired outcomes) in order to design for learning in the right direction (Wiggins & McTighe, 2005). The “backward design” is a way used to develop a curriculum by following three steps: identifying the desired outcomes, assessment criteria and methods, and instructional activities (Wiggins & McTighe, 2005). There is a mutual connection between backward design and STEAM, where STEAM reinforces and supports the backward design framework’s tenets for curriculum, instruction, and assessment through the utilization of performance tasks and an authentic learning environment (McTighe & Reese, 2013). There are also different approaches to planning an integrated curriculum, such as Drake’s (1991) approach and Beane’s (1991) approach. Both directions suggest different planning methods and designing an integrated curriculum. Drake (1991) focuses on teachers’ collaboration in planning, while Beane (1991) relies more on teachers’ co-planning with the students. The primary concern of assessment for a transdisciplinary curriculum is authenticity (Drake & Reid, 2017).

Authentic Assessment

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). Mueller (2010) defined authentic assessment as performing tasks related to the real-world where students can demonstrate meaningful application of essential knowledge and skills. Authentic assessment is a desirable tool for checking students' understanding of online learning using complex ill-structured problems, real-life scenarios, reflective blogs, and critical thinking questions (Herrington & Parker, 2013; Reeves et al., 2002). The authentic assessments allow students to have several checking points to reflect on their work, making learning more meaningful (Barnett & Ceci, 2005). Figure 2 shows an illustration of the transition from traditional assessment to a reconfigured form of authentic assessment. 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. In contrast, authentic assessment lies in performing a task, deals with real-life applications, requires construction, and applying knowledge from different disciplines, is student-centered and has direct evidence.

Figure 2

Shift the Balance of Assessment from the Traditional to the Reconfigured (Redesigned) Assessment Model

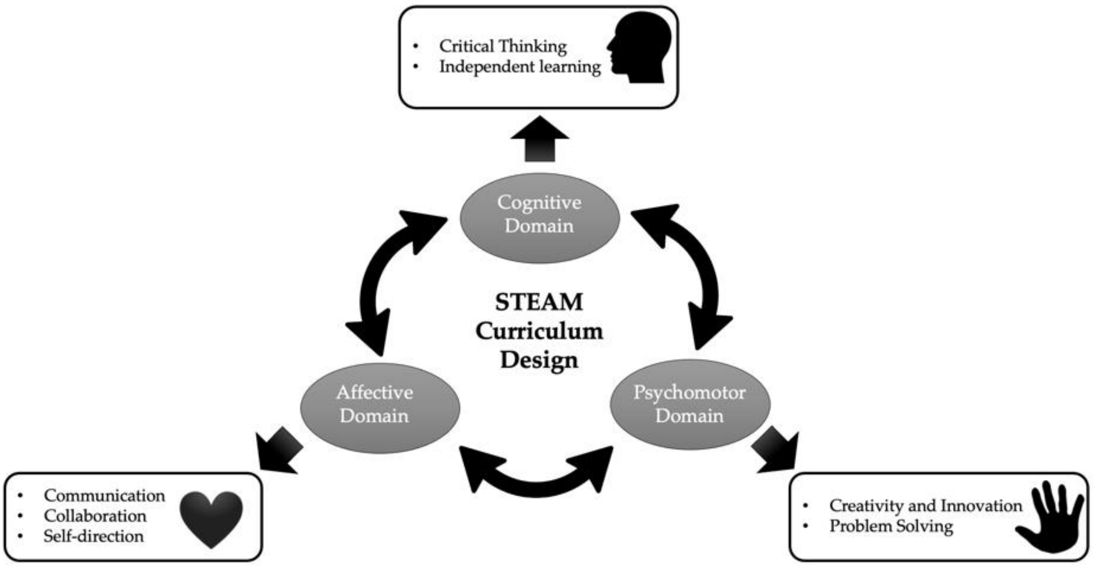


Proposed Model

According to the reviewed literature, figure 3 represents the conceptual framework whichh guides this study. In previous studies, it was stated that students' skills and competencies are developed through the cognitive, affective, and psychomotor domains that lead to transformation in students' learning (Greenhill et al., 2018; Singleton, 2015). In addition, Greenhill et al. (2018) emphasized that the design of authentic tasks using integrated knowledge can transform students' ways of knowing if cognitive, affective, and psychomotor domains are considered.

Figure 3

Proposed model which guided the study



It is important to note that Sipos et al. (2008) suggested a similar learning framework called the "Head, Hands and Heart Model" which develops students' competencies. The Head refers to learners' engagement in the cognitive domain through academic studies, inquiry, critical thinking and understanding of concepts (Singleton, 2015). Hand refers to the psychomotor domain which develops problem-solving, creativity and innovation skills, and physical work (Singleton, 2015). Heart refers to the affective domain which forms values and attitudes translated into behaviors through communication, collaboration, and self-direction (Singleton, 2015).

Aims of the Study

The lockdown of schools and universities took place in March 2020, and a shift toward online learning was planned and implemented (Dubai Future Foundation, 2020). The validity of the assessments in online settings was a challenge for schools and universities during the covid pandemic. The unfeasibility of the paper and pen assessments required private and governmental schools to shift the focus toward designing online authentic assessments which focus on critical thinking, reflection, and problem-solving skills.

There has been many researches on educational studies and the impact on students' learning during and after COVID-19 (ElSayary, 2021; Erfurth & Ridge, 2020; Di Pietro et. Al., 2020). However, this study highlights and examines suggested solutions to teach the STEAM curriculum and meet the country's vision. The study's main purpose is to investigate teachers' perceptions and practices in designing and teaching a transdisciplinary STEAM curriculum using authentic assessment in online learning. This study seeks to answer the following questions which would fulfill the main purpose of the study:

1. How does cognitive, psychomotor and affective domains considered to design authentic assessment in a transdisciplinary STEAM curriculum?
2. What are teachers' perceptions and practices in designing and teaching a transdisciplinary STEAM curriculum using authentic assessment?

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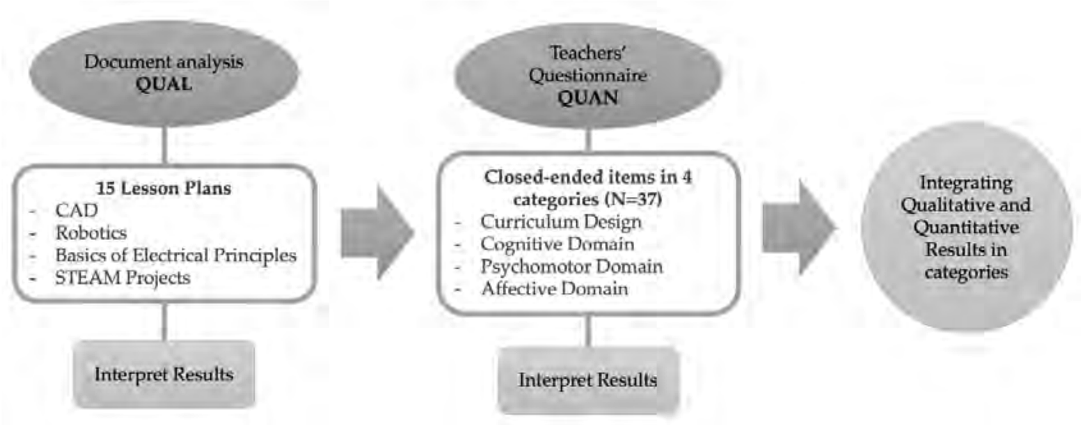
Methods

The study sought to investigate the teachers' perceptions and practices of aligning transdisciplinary STEAM curriculum planning to use authentic assessment in online learning. Creswell (2014) stated that the mixed-method design is an advanced design which uses several data collection examining the same phenomena. This research adopted an exploratory mixed-method design, began with a qualitative method (document analysis) and followed by a quantitative method (teachers' questionnaire). The rationale is to seek the development of the results from one method with other method's results, including sampling and implementation. The sequence of the exploratory mixed method data collection and interpretation is shown in Figure 4.

Figure 4

The Sequence of Exploratory Mixed Method Used Study



Participants

STEAM Lesson plans were selected for the document analysis. An extreme-case sampling was used for the document analysis. The "extreme-case" sample is proceeded in two stages. First, setting the questions that represent the extreme characteristics needed for the lesson plans. Then, selecting the lesson plans that meet all the criteria set for the document analysis. The criteria set for the document analysis includes: (i) courses with integrated disciplines, (ii) using complex technology instead of simple technology, (iii) being taught to middle and high school students. The number of document analyses used was fifteen lesson plans selected from three courses (CAD, Robotics, and Basics of Electrical Principles) and the STEAM projects.

The other sample selected for the questionnaire was teachers with the following specialization: English, Physics, Computer Science, Engineering, and Mathematics. The participants are middle and high school teachers from a private school in Dubai, United Arab Emirates. The criteria set for the participants are defined by (i) specializing in one of the STEAM subjects, (ii) having educational qualification, (iii) having five or more years of teaching experiences. The participants who met the criteria were invited to participate in the study. As the elementary teachers are specialized in early childhood and most of them were having less than five years of experience, they were excluded from the study. The target population is fifty teachers, the intended sample size was 40 teachers, and the final sample was 37 teachers. In the sample, 48.6% (n=18) of the participants were males and 51.4% (n=19) were females.

Instrumentation

The documents selected in this study are the lesson plans of transdisciplinary STEAM courses. The first course is the CAD software which is created for students in high-school. This course integrates technology, engineering, arts, and mathematics with less focus on science concepts. The second course is integrated sciences taught to middle school students, where they apply what they have learned in separate subject classes to solve real world problems and produce projects. The third course is the robotics course that integrates science, technology, engineering, and art, with less focus on mathematics. This course is taught for middle school students as part of the information technology classes. The aim of analyzing these documents is to understand and describe the design model used for the transdisciplinary courses that promote students' learning, in addition to the extent of considering students' involvement in the planning. The items of the document analysis checklist are categorized into three sections. The first section 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 (6 items). Then, this part is followed by a box for general comments for recording any important findings. The second section involves questions to understand the level of skills identified in the planning and assessments (7 items). Then, it is followed by a general comments box in order to record any important findings. The last section involves the feedback and reflection from authentic assessments used for teaching and its impact on students' learning and the time represented for students' post-conference where they can discuss feedback and setting plans to improve (5 items). Finally, this part ends with a general comment box for recording any unexpected and important findings. The document analysis checklist was sent to two experts in education studies for content validity. According to received feedback from the experts, there were no changes needed. Thus, the checklist was used in the document analysis. To assess the quality of document analysis items, two trained research assistants coded six randomly lesson plans, allowing the researcher to calculate measures of interrater reliability such as Cohen's K values. According to Landis and Koch (1977), a Kappa value greater than 0.81 is considered near perfect. The items were coded with rank 0 for the answer "No", 1 for the answer "Yes", and 2 for the answer "May be". Analysis of interrater reliability revealed almost near perfect where the lesson plan checklist items were K = 0.86.

The teachers' questionnaire consisted of two main sections: demographic information where the criteria were set and closed-ended items. A five-point Likert scale is used with the closed-ended items to feature the following responses: 5=strongly agree, 4=agree, 3=neutral, 2=disagree, 1=strongly disagree. The teachers were asked about their perceptions and practices of the tasks formed for their students regarding: the curriculum and assessment design (13 items); Cognitive domain includes critical thinking and independent learning skills (7 items); affective domain includes communication, collaboration, and self-direction skills (10 items); and psychomotor domain includes creativity and innovation and problem-solving skills (6 items). The questionnaire items were created after reviewing the literature presented in this study. The total number of items in the questionnaire is 36. The questionnaire was sent to physics, mathematics, biology, and computer science specialists for content validity. They were asked to give feedback on the instrument' suitability in addressing the research questions, the appropriateness of the items in each category and sub-category, and the accuracy of the language. The experts suggested changes in few terminologies. The reliability test was conducted using Cronbach's Alpha coefficient. In addition, the exploratory and confirmatory analysis was conducted to ensure the construct validity.

Procedure

The consent form was sent to the participants, and a full explanation was provided for the purpose of the study. Participants had the choice to participate in the study as all instruments are anonymous, and they have the option not to continue in the study.

The exploratory sequential mixed-method design was used in this study. A qualitative approach (document analysis) was used to address question 1 (How does cognitive, psychomotor, and affective domains used to design authentic assessment in a transdisciplinary STEAM curriculum?) using lesson plans. The findings of the document analysis are categorized into themes based on the framework of the study. The findings were then used to edit and inform changes to the teachers' questionnaire designed earlier to address question 2 (what are the teachers' perceptions and practices in designing and teaching a transdisciplinary STEAM curriculum?), where a questionnaire was sent to teachers through a web-survey. Handal et al.'s (2013) questionnaire score range of the means was used to describe the results as shown in table 1.

Table 1

Questionnaire score range

Score Range	Description
$1.0 \leq x < 1.5$	Very low
$1.5 \leq x < 2.0$	Low
$2.0 \leq x < 2.5$	Moderately low
$2.5 \leq x < 3.0$	Slightly below average
3.0	Average
$3.0 < x \leq 3.5$	Slightly above average
$3.5 < x \leq 4.0$	Moderately high
$4.0 < x \leq 4.5$	High
$4.5 < x \leq 5.0$	Very high

Note. (Handal et al.'s, 2013)

The qualitative and quantitative data results were presented separately and integrated into the discussion section to fulfill the study's main purpose, which is to investigate teachers' perceptions and practices in designing and teaching STEAM curriculum by using authentic assessments.

Data Analysis

Reliability and Validity

The reliability test was conducted by calculating Cronbach's Alpha coefficient. The teachers' questionnaire was piloted with 20 teachers in another school valued at 0.873, which is considered very highly reliable and suitable for the study. The reliability coefficient of the scale (Cronbach's Alpha) of the categories was determined to be 0.846 for curriculum design, 0.796 for cognitive domain, 0.753 for psychomotor domain, and 0.864 for the affective domain. Then, the survey was administered to teachers through a web-survey. A descriptive statistic was used to analyze the survey results to include mean and standard deviation.

After conducting analysis for the content validity, the construct validity was conducted by running the Exploratory Factor Analysis EFA which is a statistical analysis method used to identify the underlying relationship between measured variables.

For curriculum design, the value of Kaiser-Meyer-Olkin (KMO) is 0.635 and the Bartlett Chi-square approximation is 149.784 with $p = 0.000$. A KMO value close to 1 indicated that the correlation pattern was compact enough to produce different and reliable factors. In cognitive domain, the value of KMO is 0.688 and the Bartlett Chi-square approximation is 114.870 with $p = 0.000$. A KMO value close to 1 indicated that the correlation pattern was compact enough to produce different and reliable factors. In psychomotor domain, the value of KMO is 0.727 and the Bartlett Chi-square approximation is 169.227 with $p = 0.000$. A KMO value close to 1 indicated that the correlation pattern was compact enough to produce different and reliable factors. In affective domain, the value of Kaiser-Meyer-Olkin KMO is 0.741 and the Bartlett Chi-square approximation is 273.486 with $p = 0.000$. A KMO value close to 1 indicated that the correlation pattern was compact enough to produce different and reliable factors. The analysis results in table 2 indicates that the KMO and Bartlett sphericity tests indicated that the EFA method was appropriate for use in this study.

Table 2

Kaiser-Meyer-Olkin and Bartlett's sphericity tests for curriculum design, cognitive, psychomotor, and affective domains

Category	KMO Measure of Sampling Adequacy	Bartlett's Test of Sphericity		
		Approx. Chi-Square	df	Sig.
Curriculum Design	0.635	149.784	78	0.000
Cognitive Domain	0.688	114.870	21	0.000
Psychomotor Domain	0.727	169.227	15	0.000
Affective Domain	0.741	273.486	45	0.000

Then, the Confirmatory Factor Analysis (CFA) was proceeded to complement the results obtained with the EFA and test how well the measured variables represent the number of constructs. The Comparative Fit Index (CFI) is measured and presented in table 3. In curriculum design, all the values show a good fit of the results. In Cognitive domain, the CFI (0.99), NFI (0.99), and RMSEA (0.07) show a good fit for the results; however, the SRMR (0.0812) and the TLI (0.99) are acceptable. For the psychomotor domain, the CFI (0.99) and NFI (0.99) show good fit; while the RMSEA (0.08), SRMR (0.092), and TLI (0.99) are acceptable. Regarding the affective domain, the CFI (0.99) and NFI (0.99) are in good fit; while RMSEA (0.08), SRMR (0.077), and TLI (0.99) are acceptable.

Table 3

CFA Results of the Scales Used in the Research

Category	Fit Index	Value	Fit
Curriculum Design	CFI	0.99	Good Fit
	NFI	0.99	Good Fit
	RMSEA	0.024	Good Fit
	SRMR	0.027	Good Fit
	TLI	0.99	Acceptable
Cognitive domain	CFI	0.99	Good Fit
	NFI	0.99	Good Fit
	RMSEA	0.07	Good Fit
	SRMR	0.0812	Acceptable
	TLI	0.99	Acceptable
Psychomotor domain	CFI	0.99	Good Fit
	NFI	0.99	Good Fit
	RMSEA	0.08	Acceptable
	SRMR	0.092	Acceptable
	TLI	0.99	Acceptable
Affective domain	CFI	0.99	Good Fit
	NFI	0.99	Good Fit
	RMSEA	0.08	Acceptable
	SRMR	0.077	Acceptable
	TLI	0.99	Acceptable

According to Çelik and Yilmaz (2016), the measure of CFI ranged $0.97 \leq CFI \leq 1$ is in good fit and $0.95 \leq CFI < 0.97$ is acceptable, while NFI ranged $0.95 \leq NFI \leq 1$ is in good fit and $0.90 \leq NFI < 0.95$ is acceptable, RMSEA ranged $0 < RMSEA \leq 0.05$ is in good fit and $0.05 < RMSEA \leq 0.08$ is acceptable, and SRMR ranged $0 < SRMR \leq 0.05$ is in good fit and $0.05 < SRMR \leq 0.10$ is acceptable. In addition, Hu and Bentler (1998) assumed that the value is $0 < TLI < 1$, and proposed that $< .95$ is a cutoff value for a good fit of the TLI.

Findings

The document analysis and the teachers' questionnaire results were interpreted separately in the below sections.

Document Analysis

Table 4, 5, 6 and 7 present the analysis of the lesson plans in the following categorical themes: curriculum & assessment, cognitive domain (critical thinking and independent learning), psychomotor domain (creativity, innovation and problem-solving), and affective domain (communication, collaboration, and self-direction).

Table 4

The Analysis of Curriculum and Assessment Design and Planning of the Lesson Plan Documents

Category	Analysis
Curriculum & Assessment	The lesson plans of courses and projects focus is on the concepts, enduring understanding, generalizations, and principles and theories. The lesson plans did not specify the tasks of each subject in the planning of the projects. Tasks were presented as a whole project task. Examples of the projects were a rover and a robotic hand. The purpose of the first project is to design and build a rover with scientific instruments to determine whether Mars could be an alternative planet for people. Students programed the rover to use a color sensor on several rock samples. For the robotic hand, students built a sensor-equipped glove to control a robotic hand. They developed design solutions to improve the functioning of their robotic hand using sensor data. Their design was able to lift 0.5 kg of weight vertically up and down as well as rotate. The used assessments were authentic tasks in the shape of projects, real-life problems, and performance tasks.

Table 5

The Analysis of Cognitive Domain (Critical Thinking and İndependent Learning) of the Lesson Plan Documents

Category	Analysis
Cognitive Domain	Students had the opportunity to discuss the connection between mechanical and electrical parts of their work and its value in their lives. They used their e-journals to 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 by using their mathematical and analytical skills. In addition to these assessments, the robotics lessons also used performance tasks and e-journals as essential assessments. The process, stages and analysis of the projects were discussed with the students through using miro.com (an application of mind mapping). Students used a weekly discussion blogs to reflect on the process and progress of their projects.

Table 6

The Analysis of Psychomotor Domain (Creativity and İnnovation And Problem-Solving) of the Lesson Plan Documents

Category	Analysis
Psychomotor Domain	The lesson plans include various activities to address diverse learning needs and are aligned to the culminating assessment. In the lesson plans, teachers referred to certain rubrics that were used in accomplishing the projects. They set certain stages to facilitate student projects. The lesson plans of the courses were included reflection and discussion about the students' projects where they have to connect what they learn in courses to apply it in their projects. The lesson plans show that students led the learning process to identify the problem, suggest ideas, discuss the freehand drawings, research, complete CAD drawings, formulate surveys, and present their plans. Instructions about using certain applications were provided in the lesson plans. Students were required to use augmented reality application on their iPads called Jig Workshop and Assemblr.

Table 7

The Analysis of Affective Domain (Communication, Collaboration, and Self-Direction) of the Lesson Plan Documents

Category	Analysis
Affective Domain	In the main part of the lesson, the activities are introduced and students have the time to work actively in groups (breakout rooms) to complete their tasks. For example, students should work together to have at least four ideas approved by their teacher. It was also mentioned in planning, scaffolding and peer teaching to clarify concepts when needed within their groups. In addition, there was certain tasks which were done on campus with consideration of social distancing to create and test their projects. Students used different collaborative apps such as iCloud (pages, keynotes, numbers), google documents, and canva.com to facilitate the flow of the project's process. Dialogues between student-student and student-teacher were mentioned in the plans to give feedback, reflect critically, and change their perspectives. This was facilitated by using Microsoft Teams and Zoom breakout rooms.

Teachers' Questionnaire

Curriculum Design: Table 8 represents the mean and standard deviation of the curriculum design category. The highest item in the curriculum design category is shifting from STEM to STEAM. It allows students to think divergently where students create different products based on their points of view; mean=4.15, which is considered high. Two items that are viewed as moderately high: Students are not assessed in the same way since they do not learn in the same way (mean=3.72); and each activity in authentic assessment includes detailed instructions and guidelines for students to ensure the completion of the requirements (mean=3.91).

Table 8

The Mean and Standard Deviation of the Questionnaire Items in the Curriculum Design Category

Curriculum Design	N	Mean	Std. Dev.
1. Integration between disciplines allows for more concepts that can be taught in less time and in higher levels.	37	4.24	0.862
2. Shift from STEM to STEAM allow students to think divergently where each create different product based on their points of views.	37	4.35	0.633
3. Design of transdisciplinary curriculum relates closely to career goals and practice.	37	4.16	0.727
4. The course requirements, instructional activities, and assessments are designed to a certain degree that allow students to experience the fidelity of authentic tasks.	37	4.00	0.849
5. The design of transdisciplinary curriculum using authentic assessment afford student engagement and active online learning.	37	4.02	0.985
6. The design of authentic assessment used transdisciplinary curriculum provide challenge, interest, and motivation to learn online.	37	4.24	0.862
7. Transdisciplinary curriculum focuses on different ways of looking at the world.	37	4.02	1.092
8. The authentic assessment is designed to give feedback to students in a more motivational form.	37	4.08	0.924
9. Authentic assessments take time at both creation and grading stages.	37	4.16	0.928
10. Students are not assessed in the same way since they do not learn in the same way.	37	3.72	1.261
11. Each activity in authentic assessment includes detailed instructions and guidelines for students to ensure the completion of the requirements.	37	3.91	1.089
12. Authentic assessment aims to make connections among contents and apply new knowledge into meaningful and relevant tasks.	37	4.10	0.936
13. An indicator of student attainment to their knowledge, skills, and attitudes is completing relevant activities and investigations.	37	4.21	0.946

Cognitive Domain*:* Table 9 represents the mean and standard deviation of the cognitive domain. The item means ranged (4.0 < $x \leq$ 4.5), which is considered to be high.

Table 9

The mean and standard deviation of the questionnaire items in the cognitive domain

Cognitive Domain	N	Mean	SD
Critical Thinking			
1. Students gather, evaluate, and synthesis information from different sources.	37	4.45	0.605
2. Logically connect among ideas, contents, concepts, and area of learnings.	37	4.21	0.750
3. Students use integrated knowledge to solve problems logically.	37	4.29	0.845
4. Students reflect on their own beliefs, values and points of views from local and global perspectives.	37	4.45	0.605
Independent Learning			
1. Students use extensive range of resources and technologies independently.	37	4.37	0.681
2. Students set clear and challenging targets that consistently be achieved and adapted in the light of online experience.	37	4.18	0.659
3. Students reflect and evaluate their own learning and outcomes of that learning.	37	4.13	1.084

Psychomotor Domain*:* Table 10 represents the mean and standard deviation of the psychomotor domain. The item means ranged (4.0 < $x \leq$ 4.5), which is considered to be high.

Table 10

The Mean and Standard Deviation of the Questionnaire Items in the Psychomotor Domain

Psychomotor Domain	N	Mean	SD
Creativity and Innovation			
1. Students generate innovative ideas and ways of thinking in solving problems.	37	4.29	0.701
2. Students use an extensive range of subjects' techniques as part of the creative process.	37	4.24	0.722
3. Students are open to challenges, difficulties and risk-taking	37	4.21	0.712
Problem Solving			
1. 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.	37	4.32	0.668
2. Students use technology to provide innovative solutions for problems that fit to the purpose.	37	4.37	0.861
3. Students solve an ample range of problems between well- and ill-structured.	37	4.18	0.739

Affective Domain*:* Table 11 represents the mean and standard deviation of the affective domain. The item means ranged ($4.0 < x \leq 4.5$), which is considered to be high.

Table 11

The Mean and Standard Deviation of the Questionnaire Items in the Affective Domain

Affective Domain	N	Mean	SD
Communication			
1. Students communicate using an extensive range of methods: verbal, written, visual, and/or non-verbal.	37	4.48	0.606
2. Students organize the content of their thoughts and communication into a logical and coherent whole.	37	4.48	0.692
3. Students use a wide range of modern technologies effectively and confidently as a means of communication.	37	4.48	0.650
Collaboration			
1. Students work productively with others from a wide range of social and cultural backgrounds.	37	4.27	0.769
2. Students argue a point of view respectfully when challenging with the differing views of an individual or the team.	37	4.40	0.762
3. Students work with others to guide, counsel and motivate team members to achieve team goals.	37	4.48	0.650
Self-direction			
1. Students initiate a range of simple and complex activities and tasks which advance their knowledge, understanding and skills.	37	4.29	0.938
2. Students define and work towards goals and targets without need to be pushed, driven or managed by others.	37	4.21	0.821
3. Students recognize opportunities for self-advancement and opportunities that will benefit others.	37	4.27	0.902
4. Students take responsibility and make decisions to resolve issues.	37	4.32	0.709

Figure 4 shows a comparison of the means of the main categories: curriculum design, cognitive, psychomotor, and affective domains. The curriculum design scored the lowest (mean = 4.09, SD = 0.603), while the affective domain scored the highest (mean = 4.37, SD = 0.603). Cognitive domain (mean = 4.30, SD = 0.523) is higher than psychomotor domain (mean = 4270, SD = 0.548). According to Handal et al. (2013), the score range of the means of the main categories is considered to be high ($4.0 < x \leq 4.5$).

Figure 4

Comparison of The Means in The Main Categories

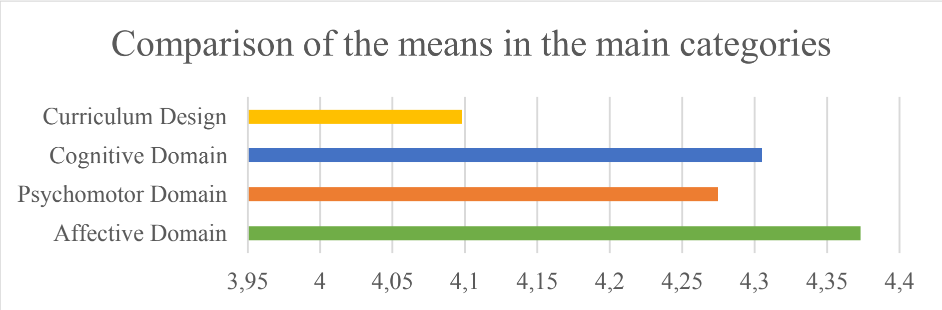
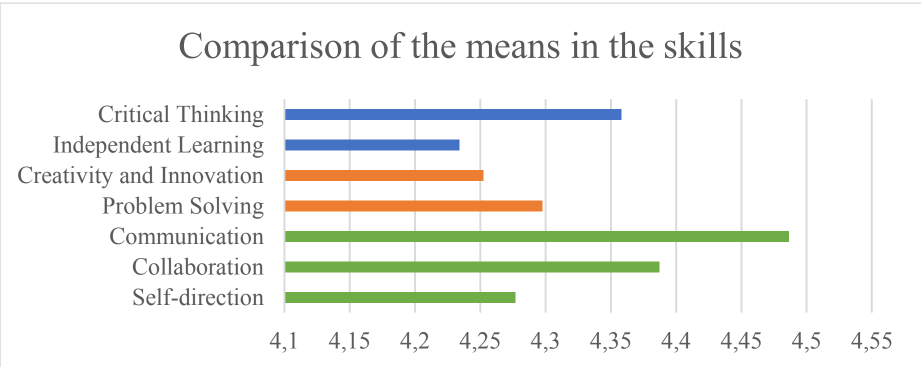


Figure 5 shows a comparison of the means of the sub-categories (skills): critical thinking and independent learning of cognitive domain, creativity and innovation and problem-solving in psychomotor domain, and communication, collaboration, and self-direction in affective domain. The independent learning skill scored the lowest (mean = 4.23, SD = 0.675). The following skills are scored high in the following order: the creativity and innovation (mean = 4.25, SD = 0.552), self-direction (mean = 4.27, SD = 0.765), and problem-solving (mean = 4.29, SD = 0.632). The highest means were found in the following: critical thinking (mean = 4.35, SD = 0.593), collaboration (mean = 4.38, SD = 0.606) and communication (mean = 4.48, SD = 0.611). According to Handal et al. (2013), the score range of the means of the main categories is considered to be high ($4.0 < x \leq 4.5$).

Figure 5

Comparison of the Mean in the Sub-Categories (Skills)



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Discussion

This study yielded professional implications by investigating teacher perceptions and practices in designing and teaching a transdisciplinary STEAM curriculum using authentic assessment in online learning environment.

Designing a STEAM Curriculum Using Authentic Assessment

The design of the STEAM curriculum supports the planning process of Drake and Burns (2004). It requires teachers to collaborate effectively among departments to design integrated units, read across the curriculum vertically and horizontally, choose an appropriate theme, brainstorm activities, create rich assessments, create guided questions, and design instructional activities. This result is consistent with Leopone (2016) study, which stated that the planning of integrated curriculum improved teacher collaboration and encouraged them to share new strategies. However, teachers in this study mentioned that designing the curriculum through authentic tasks were time consuming. The study results agree with Beane, Dewey, Whitehead, and Gardner, who proposed that teaching less meaningful information in more depth based on student interests, would be more beneficial and encourage students to engage in higher-order thinking (Leopone, 2016).

The STEAM project design supports Beane's (1991) work, who suggested that planning a transdisciplinary curriculum should be based on student interests, and involvement in the planning process. Learning is more effective when students investigate the questions that they have posed. An authentic assessment is a kind of assessment *as* learning in which the primary purpose is sustainability (Almqvist et al., 2017), and students are engaged as critical assessors (Earl, 2013). In this study, it was reflected in planning which involved several tasks used for authentic assessment. Accordingly, students were forced to create several checkpoints for self-evaluation and reflection, such as collaborative activities, assignments, projects, problems, and journals. The analyzed lesson plans showed the shift from regular formative assessment to authentic assessment, which involves many tasks and allows students to self-assess, reflect, and obtain 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 the teacher responses. So, transdisciplinary curriculum allowed for learning both the breadth and depth of knowledge.

The results of this study support those of Mutch (2012), who emphasized the vital collaboration between teachers and students in co-constructing and designing authentic assessment tasks. This result also confirms Black & William's (1998) results, which showed that the design of authentic assessment used transdisciplinary curriculum inspired teachers to shift the focus from teaching to learning. Teachers guided students and considered different learning outcomes to accommodate and encourage unexpected, unique products that promoted student creativity. Teacher perceptions, practices, and confidence increased, which confirms Nadelson et al. (2013) results.

Designing and Teaching STEAM Curriculum Using Online Authentic Assessment

Regarding the cognitive domain, the teachers responded that students were able to reflect on their own beliefs, values, and points of view from local and global perspectives using different methods such as e-journals, discussion forums and blogs. The transdisciplinary curriculum design using authentic assessment allowed for a logical connection among ideas, contents, concepts, and learning areas. Students gathered, evaluated, and synthesized information from various sources. The teachers also emphasized that students could set clear and challenging targets that could consistently be achieved, adapted, and evaluated. During the project process, students used e-journals that allowed them to think about the meaning and reasoning of hypothesis. They completed data collection and analysis by using their mathematical and analytical skills virtually through miro.com. Greenhill et al. (2018) emphasized that self-examination is used to reflect and brainstorm how and why learners think certain things in specific ways. The teachers responded that feedback significantly impacted student work and changed their perspectives during the learning process. Students became aware of their strengths and weaknesses, especially when feedback was given to them earlier, where students adapted the goals that they had set, which in turn helped them meet the desired outcomes for the tasks. The purposeful critical analysis of knowledge and experiences allows learners to achieve more profound meaning and understanding (Greenhill et al., 2018).

For the psychomotor domain, the teachers emphasized that students led the learning process. However, they faced some challenges compared to other domains. They had to identify the problem, suggest ideas, discuss the freehand drawings, conduct research, complete CAD drawings, formulate surveys, and present their plans. Teachers stated that students organized their work while solving problems that ranged widely from well- and ill-structured. Previous studies noted the importance of psychomotor domain in designing constructivist activities within integrated curriculum (Gülen & Yaman, 2019). It is beneficial in developing student problem-solving, creativity and innovation skills (Greenhill et al., 2018; Singleton, 2015). Students used their previous learning and applied it to new situations and interconnected divergent and convergent thinking to determine the right route to follow. Teachers mentioned that students completed a research project or open-ended investigation about a complex topic using higher-order thinking skills (analysis, synthesis, critical thinking, and creativity) to support their solutions and claims. This was also mentioned in the lesson plans where students were required to use augmented reality applications (Jig workshop and Assemblr) to support their projects. As mentioned in the literature review, three elements promote student creativity and take them to a higher level of thinking: integrated course, problems or projects; positive encouragement and feedback; and rewards for completing a task (Costantino, 2018; Istiyono, et al., 2020). Another study of Sarı et al. (2020) highlighted the positive effect on the development of scientific process skills and STEM awareness.

In the affective domain, the teachers agreed that students communicated using an extensive range of verbal, written, visual, and nonverbal methods. Based on teacher responses, the affective domain scored the highest. These results are confirmed in the lesson plan analysis, where it was mentioned that different apps were used to facilitate student collaboration and communication such as iCloud, google docs, and miro.com. In addition, there was certain tasks that were done on campus with consideration of social distancing to create and test their projects. Accordingly, the collaboration and communication skills sub-categories have the highest scores of teachers responses. Samsudin, et al. (2020) emphasized the importance of using authentic tasks while teaching integrated STEM projects due to the positive impact occurred on student communication and collaboration skills. Students were able to organize the content of their thoughts and communication into a logical and coherent whole. This was mentioned in the lesson plans where students met in breakout rooms to discuss their work. It is aligned with Fook and Sidu (2013), who emphasized integrating knowledge in solving real-world problems and using assessment to diagnose student abilities and progress towards achieving the desired outcomes. The teachers stated that the students used a wide range of modern technologies effectively and confidently to communicate. They stated that the students worked with others to guide, counsel, and motivate team members to achieve team goals. The teachers mentioned that the students argued a point of view respectfully when challenging different views. Those results are supported by a previous study that emphasized the peer group dialogue which alternates between the whole class activity and student discussion in small groups (Black et al., 2011). The students initiated a range of simple and complex activities and tasks which advanced their knowledge, understanding, and skills. The students planned, defined, and worked toward goals and targets independently, took responsibility, and made decisions to resolve issues. These values correlate reasonably well with Singleton (2015), who emphasized that life quality depends on the relationships with environments, communities, and personal relations.

Conclusion and Recommendation

The purpose of this study is to investigate teacher perceptions and practices in designing and teaching transdisciplinary STEAM curriculum using authentic assessment in online learning. The questions of the study have been addressed and confirmed the main purpose of the study. The results show that the transdisciplinary STEAM curriculum is constructively aligned to the authentic assessments. There was clear alignment between what students need to know, what they will do, and what they will be. This model emphasizes the use of backward design (Drake & Burns, 2007). The authentic assessments are "assessment as learning," where several checkpoints of feedback, self-assessment, and critical reflection, reflect to the cognitive domain. The results agree with the previous studies which highlighted that authentic assessment is a desirable tool used for checking student understanding of online learning using complex problems, real-life scenarios, reflective blogs, and critical thinking questions (Herrington & Parker, 2013; Reeves et al., 2002). Teachers started to shift their focus from teaching to learning, where authentic assessment design forced them to create several checkpoints for student self-evaluation and reflection. As reported by many researchers, the authentic assessment tasks inspired teachers to focus more on learning (Sousa & Pilecki, 2013), and developing higher-order skills (McNeill et al., 2012).

All teachers agreed that designing a transdisciplinary STEAM curriculum through authentic assessment is time-consuming and requires highly effective collaboration and communication among departments. It has been stated by Drake and Burns (2007) that the integrated curriculum is challenging as it requires high collaboration among teachers. On the contrary, the results of Leopone's study (2016) emphasized that teacher collaboration has been improved while planning the integrated curriculum. Furthermore, the instructional activities are not easy to design in a way since requiring students to critically reflect on their learning several times during the time required to complete the task.

In addition, Mutch (2012) emphasized role 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 result 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 guide students and leave their learning outcomes open-ended to accommodate and expect the unexpected, unique products that encourage their creativity (Cheng, 2015; Earl, 2013). It is interesting and important to note that the teacher 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 teacher perceptions, practices, and confidence increased. 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 with a complex integration where the boundaries of subjects were blurred. Further studies are recommended about students' digital competencies, engagements in online learning, teaching presence, and the correlation among students, skills developed in schools and the job market needs.

The design of authentic assessments used in the current study has several authentic tasks such as collaborative activities, assignments, projects, problems, reflective blogs, and e-journals. This confirms Lichfield and Dempsey (2015), who shifted the focus from traditional formative assessment to authentic assessment tasks and allowed 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. The planning shows the several tasks used for authentic assessment and the student 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 teacher responses. They stated that the transdisciplinary curriculum allows for learning both breadth and depth of knowledge.

One of the main limitations of this study was that student e-journals were not analyzed, which could have added a deeper understanding of the challenges that they faced and explaining the discrepancies of the results in the three domains of learning. The most significant limitation was that the skills acquired within each type of learning were intertwined in a very complicated way, which caused the researcher to rely heavily on multiple forms of data to validate the results. The sequential method required to follow one method after the other, and the challenge for the researcher was trying to determine the point at which the results from the first phase would become the focus of the investigation in the second phase. Finally, the lockdown of the pandemic put teachers in an uncomfortable situation and forced everyone to communicate virtually, which made it difficult to interview teachers.

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