

From STEM to STEAM in ancient age architecture

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Abstract

This research aims to identify the effects of a science, technology, engineering, arts and mathematics implementation in the ancient age architecture field on the achievements of the undergraduate students and their science, technology, engineering and mathematics (STEM) perceptions. The research was based on the explanatory design, while the experimental design with pre-test and post-test control groups was carried out in the quantitative component of the study and the case study was carried out in the qualitative component. In the first stage, the study context, selections of the groups, development and implementation of the pre-test and formation of the project groups were realised. The second stage was accomplished by carrying out the study in accordance with the determined plan, implementations of the practices, realising the post-test and conducting the interviews. Finally, a significant difference was observed between the achievement test mean scores of the experimental group and the control group in favour of the experimental group.

Keywords: STEAM approach, ancient age architecture, STEAM achievement, STEM perception.

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1. Introduction

Science, technology, engineering and mathematics (STEM) education is crucial for purposes such as taking great steps towards industrialisation, having the promise in the global market, providing economic advantages and training qualified individuals for current and future new generation business areas. That is why educating STEM literate students given due importance to STEM education from kindergarten to university, enabling these students to have individual competences in arts and cultural fields ought to take place among the main goals of the countries in terms of arts and cultural developments. In recent years, efforts were made to integrate arts into STEM education in addition to science, technology, engineering and mathematics fields. Yakman (2008) stated that arts and aesthetics should not be ignored in innovative approaches in which arts was integrated into STEM. Science, technology, engineering, arts and mathematic (STEAM) is defined as the inclusion of liberal arts and humanities in STEM education (Spector, 2015). STEAM is also to enable students to discover their creativity and obtain art products by improving their problem-solving skills within a holistic and positive perspective (Herro & Quigley, 2017).

Students gain observation, visualisation, hands-on creativity skills and self-confidence with arts in the education process. These skills are also based on scientific thinking (Cantrell, 2015). Arts can teach to observe and think deeply about instances, situations and objects. When students are asked to draw something, they need to look closer at them and examine them more carefully so that they more accurately observe the lines and shapes of the objects they depict. So, they can learn to see even the slightest differences (URL, 1). As students learn to think spatially, they gain the ability to see a three-dimensional space observing a two-dimensional drawing. This is a skill that engineers, architects and scientists need, and at the same time, it can enable students to understand complex concepts easier. Students, who see how the parts of the system come together, how they interact with each other and how they separated from each other, can more easily understand how the system runs (Yokana, 2014). In addition to the science and mathematical skills to which they must compete, individuals must be encouraged to have the creative thinking ability that emerges with a proper arts education in the new global context (Eger, 2011). STEAM can enable educating creative and innovative individuals required to increase competitive power in the global market in the twenty-first century (Rabalais, 2014).

1.1. STEM in ancient age

Archeology is one of the disciplines with rich cultural background. Archeology studies are anything that is artefact and the product of human thought (Basaran, 1998). Therefore, any study to be carried out in order to reveal an issue in the field is in its scope (Hurcombe, 2013). The reason why the piece was made, applied techniques and materials used are among evaluation criteria (Mathieu, 2002). In particular, the techniques used in some architectural pieces designed in ancient time are still issues of concern. However, in addition to processes involved in the construction of some architects even a little, the drawings that provide information about the tools and machines used in the architecture even in limited numbers reached the present day. For instance, ancient writers such as Alexander Heron, Vitruvius, Frontinus and Plinius present information about ancient technology and architecture. According to the information received, this architecture first needed a quarry that provided proper stones to construct the piece. Blocks obtained from stone quarries by various methods were processed with rough lines for ease of transportation. Fine workmanship of these blocks that were carried with sleds, logs, wheels or cars was realised in the construction site (Bingol, 2004). A wide variety of stone tools were used for fine workmanship (Bingol, 2004; Wright, 2005). It is also known that turning benches were used in the construction of pillars and cylindrical architectural components (Kretschmer, 2000).

Various tools such as crane, lever, cradle, incline ramp, pulley, spinning wheel and windlass operated with human and animal power were used in the placement of the completed architectural

components (Bingol, 2004). For instance, Vitruvius, from ancient writers lived in BC 90–20, gives information on two types of winches (Vitruvius, 1998). Based on the descriptions of Vitruvius, drawings and animations about winches were also made in the modern literature (Hodges, 1992; Kretzschmer, 2000; Landels, 1998). Even though they have not reached the present day, ideas can be obtained on their capacities with day-preserved structures. For instance, the pillar headings of the Parthenon temple in the Acropolis of Athens have a weight of 9 tons each and need to be lifted to a height of 10.5 meter (Landels, 1998). What sort of technique did they have at that time? Today, the answers to these sorts of questions are given in cooperation with different science disciplines and the results are interpreted (Duru, 2014). Large stone blocks were used in the pyramids which were built 4,500 years ago and still standing. How these blocks were moved and lifted is not known as there is no certain data available on this manner. To solve this problem, a reel that can withstand large weights was produced and tested using three-dimensional modelling and calculations. At the end of the study, it was understood that the reel pulls stone back should withstand high pressure. The reel must be large for this. Furthermore, it was understood that a rope with an appropriate thickness for the reel should be used so that it cannot break and can bear weight (Blakely & Blakely, 2014). Such studies illuminate the construction process of the architectural pieces made in the past periods and guide future studies.

In this research, a modelling study of Parthenon temple at Dor, which was known to be made in ancient times, was carried out with the STEAM approach. Thus, the emergence of architectural construction was revitalised and presented in three-dimensions fictionalising the analogy of STEAM used at that time. Counterparts of winches and reels used that time were animated with toy blocks and used in the construction of the architecture. In addition, the wooden blocks for the stones of the temple were cut, sanded and shaped like the stones were processed in the quarries, making them appropriate for the structure. In the construction process, the civil engineering knowledge was utilised and the book entitled the 'Archaeology and Civil Engineering Joint Practices' was benefited in this context (Toprak et al., 2010). Mathematical calculations were made for the temple to increase the resilience and provide a symmetrical layout.

1.2. Literature review and purpose of study

It was emphasised in many studies in the literature that STEAM is a complementary set of disciplines that improves critical thinking, complex problems solving and analytical thinking skills of the students by enabling them to combine various topics and apply to real life (Baker, 2014; Guyotte, Sochacka, Costantino, Kellam & Walther, 2015; Henriksen, 2014; Henriksen, DeSchryver, Mishra & Deep-Play Research Group, 2015; Kwon, Nam & Lee, 2012; Lee & Park, 2010; Miller & Knezek, 2013; Pollock, Murray & Yeager, 2017; Quigley & Herro, 2016; Sharapan, 2012; Sochacka, Guyotte & Walther, 2016; Sousa & Pilecki, 2013; Vanasupa, 2012; Yakman, 2008).

Baker (2014), who aims to increase interests in STEM field career, stated in the arts education report about moving from STEM to STEAM that arts offers a unique and valuable way to grow in intellectual, social and emotional respects, and arts education increases students' test scores and their commitment to the school. According to Baker (2014), while competing with other societies around the world, arts aspect of STEM that would provide innovation to take the country forward is missing. As arts improves creativity, problem solving, flexible thinking and risk taking skills which form the basis of the innovative research of arts students, it has to go hand in hand with science, technology, engineering and mathematics. STEAM is a bridge to connect STEM and arts topics and stimulate innovation needed to solve real-world problems (Yokana, 2014). Belardo (2015) stated that STEAM is a bridge to fill the gap between science and arts and shows many similarities within science and arts and the way STEM can turn into STEAM in the class.

One of the most fundamental features that the STEAM education model aims to improve is the creative personality (Kwona, Namb & Lee, 2011; Lee, 2005). Creativity is often described as the ability

to develop original and functional ideas, behaviours or products and is seen as the ability to adapt to individual, situational and cultural variabilities (Martinsen, 2011; Runco, 2004).

Liao (2016) stated that it is a cross-disciplinary transitions and integration of arts into STEM education. The integration of STEM into arts education was highlighted in the study. For this, it was emphasised that STEM applications should be understood well first and pointed out that STEM is a phenomenon which an innovative society needs to live.

The idea of ‘Arts + STEM, gives a rich learning experience for an individual’ comes at forefront in the literature (Belardo, 2015, s. 20). Learning to use a critical and creative mind to solve a problem also develops the twenty-first century skills while building a personal and meaningful link to one’s daily life. STEM practices in archaeology that examines artefacts and reveals a phase of mankind history with each of these pieces help to understand science, technology, engineering and mathematics works in the past. At the same time, it is likely that involving in STEAM practices would contribute STEM disciplines achievements, interests, attitudes and career perceptions of individuals. In this context, no study that examines the effects of the STEAM approach applied in archaeology within ancient architecture on academic achievement and STEM perception seems to appear in the literature. It is considered that this present study would contribute to the relevant literature in this regard. The following two questions were sought within the scope of the study:

1. What is the effect of STEAM approach on academic achievement? In which direction was this effect the most?
2. What is the effect of the STEAM approach on STEM perceptions of participants?

2. Methodology

In this study, a mixed method was designed in which quantitative and qualitative data instruments were administered to identify the impact of the STEAM approach on academic achievement and STEM perceptions of second-year students in the archaeology department. Creswell (2012) stated that the mixed model is collecting and analyzing quantitative and qualitative data together. The research was based upon the explanatory design from mixed models. The research was carried out in two stages. The first state is the quantitative component of the research. In this stage, an experimental study with pre-test and post-test control group was realised. Experimental designs are confronted as designs with the highest scientific value in the literature (Karasar, 2007). Necessary measures were taken for internal and external threats affecting the research, such as data collection tools, pre-tests, subject maturation and reactance effect (Buyukozturk, 2011) and were mentioned in some progressive stages of the research. The scheme of the implementation model of the study is given below.

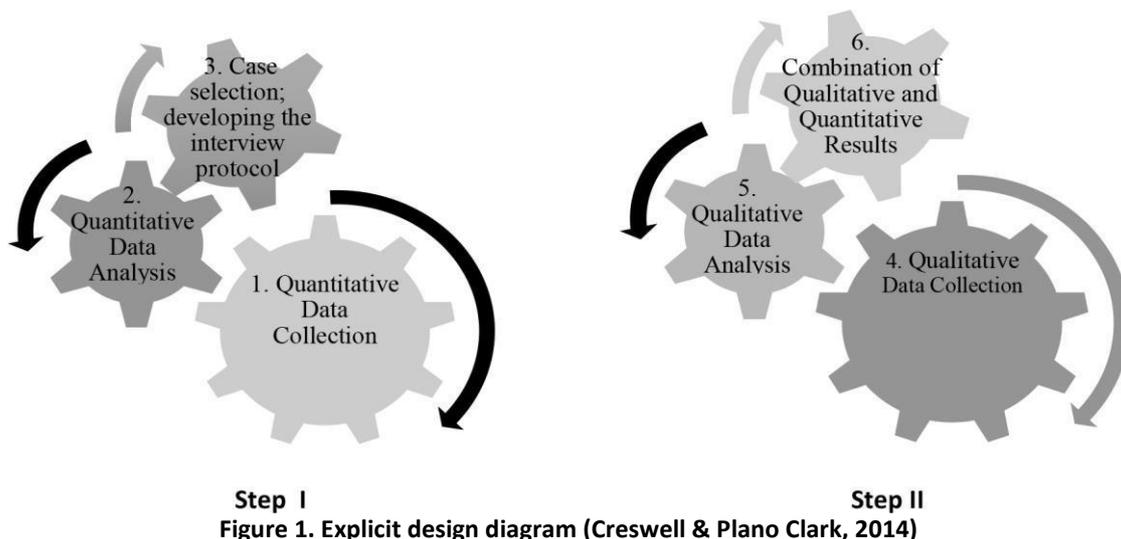
Table 1. First stage implementation model of the research

Group	Pre-test	Implementation	Post-test	Retention test
G1	T1	D1	T2	K1
G2	T3	D2	T4	K2

G1 = Group 1 (The experimental group), T1 = pre-test, D1 = the experimental study, T2 = pro-test, K1 = retention

G2 = Group 2 (The control group), T3 = pre-test, D2 = current programme, T4 = post-test, K2 = retention

The second stage of the research was realised on the qualitative component. At this stage, the case study was carried out. Face-to-face interviews were conducted with the experimental group students. The diagram prepared to describe the research design is presented in Figure 1.



2.1. Study group

This research was carried out within the archaeology undergraduate department, which has been active for 5 years, in Karamanoglu Mehmetbey University in Turkey. The participant group of the study was formed by the experimental and control groups, selecting randomly from second year 38 students studying in the archaeology undergraduate programme during 2016–2017. The main factor in the preference of the study group was that the students did not previously participate in STEM or STEAM activities and had basic knowledge of ancient architecture. The scores of the achievement test applied just before the research indicated that the groups were at the similar level with each other. Thus, one of the classes was assigned as the control group (19) and the other as the experimental group (19). Another factor in the selection of the study group was the easy access to the group by the researcher. This sampling method provides quickness and practicality for the research (Yildirim & Simsek, 2006). Another important factor in the preference of the group was that the department has an appropriate laboratory environment to realise STEM activities. The reason to select second-year students was that they had preliminary knowledge about basic archaeology and general culture courses. A descriptive analysis of the study group is given in Table 2.

Table 2. Descriptive characteristics of the participant group

		The experimental group	The control group
Gender	Female	9	10
	Male	10	9
Total		19	19

In the descriptive analysis of the randomly formed study group, there were 9 females and 10 males in the experimental group and the control group had 10 females and 9 males. A total of 38 participants were included on a voluntary basis in the research.

2.2. Data collection instruments

Quantitative and qualitative data tools were used together in the study. The quantitative data tool was applied to both experimental and control groups. In this context, the STEAM achievement test developed by the research consists of five sections. The qualitative data collection tool, 'Imagine STEM', is a visualisation consisting of a single question.

2.3. Development of STEM achievement test

In the research, an achievement test was prepared within the context of the construction of ancient temples in the ancient architecture course delivered in second year Fall term in the archaeology undergraduate programme. The 26 questions selected from the question pool were composed of five sections including science, technology, engineering, arts and mathematics. It was taken into consideration that the questions related to STEM disciplines were appropriate for the class level and hierarchical. The prepared achievement test was evaluated by two expert academicians in the science field, one in the mathematics field, one in the archaeology field and one in the measurement field. A question which was not appropriate for the level of the students and not clear was removed from the test.

Bloom taxonomy was taken into account to find out how the STEM education would affect the cognitive levels of the students and a table of specifications was prepared accordingly when designing the questions. 25 questions were included in the achievement test, which was finalised with expert opinions. In order to carry out the validity and reliability controls for the questions, a pilot study was realised with 170 students with a similar group level studying in archaeology programmes of different universities. Using the SPSS 24 programme, the internal consistency coefficient KR-20 values were calculated and the item difficulty and item discriminant indices were examined. Sci2, Sci4, Tech1 and Math3 questions, whose item discrimination indices were below 0.30, were removed from the test. Eventually, the discipline disposition of the test with 21 questions is as follows: three questions in science, three questions in technology, six questions in engineering, three questions in mathematics and six questions in arts.

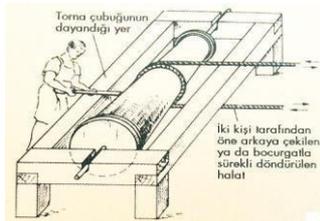
A question in science:

Which of the following is true in the context of physics rules of the lever?

- (A) The temple is being cleaned.
- (B) Robustness of the temple is being tested.
- (C) The architectural pieces of the temple are being lifted and placed.
- (D) The height of the temple is being measured.



A question in technology:



Which of the following architectural elements can be made apart from the pillar with the ancient lathe machine shown in the picture?

- (A) Architrave
- (B) Triglyph
- (C) Frize
- (D) Ekhinus

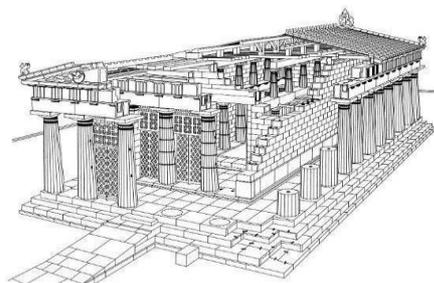
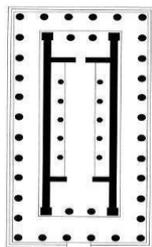
A question in engineering:

In order to build a temple with symbols C, PB, KR, AR, PH and FR which sequence from bottom to top, you have to follow?

C: Cranial PB: Pillar Body KR: Krepis AR: Architrave PH: Pillar Header FR: Frizew

(A) C-KR-PB-AR-FR-PH (B) KR-PB-AR-C-FR-PH (C) KR-PB-PH-AR-FR-C (D) PB-KR-AR-PH-C-FR A

question in arts:



Which layout is the temple seen in the next picture?

- (A) Corinthian
- (B) Dor
- (C) Ionic
- (D) Tuscany

A question in mathematics:

Math.-1. What is the ideal architrave length if the distance between the centre points of two pillars in a temple is 3 m?

- (A) 2.5 m
- (B) 4.5 m
- (C) 3 m
- (D) 2 m

The mean of the item difficulty index was 0.66 and the mean of the item discrimination was 0.42 in the test. According to the literature, it ought to be cared that the mean of item difficulties indices of items in an achievement test is 0.50 and indicates a wide range to address all capability levels. In this regard, the test is slightly above the moderate level. Furthermore, the difficulty level of the test items between 0.30 and 0.80 in item discrimination indices indicates that 30–80% of the test takers need to answer correctly (Tan, 2006). Thus, it can be said that the test has a high-level distinctive feature. The Kuder Richardson 20 value of the final test is 0.72.

2.4. Imagine STEM form preparation process

An unstructured form to obtain a visual response was developed by the researcher as a pre-test and post-test to identify STEM perceptions of the students in the experimental group participating in the STEAM activity. The studies of Radloff and Guzey (2016) and Akaygun and Aslan-Tutak (2016) were inspired when this form was developed. Participants were asked to draw the STEM concept in their minds by using initial letters S-T-E-M in the form developed by the researcher. One of the most important reasons for this activity was that visual elements could be beneficial to explore the outputs of the STEM education.

It is important to emphasise that the STEM visual representations (Peek, 1993) ought to be included in order to maintain attention and motivation (Cook, 2006) and add information that cannot be collected literally (Mayer, Bove, Bryman, Mars & Tapangco, 1996) and to increase learning through the relevant text. Comparisons were made with the form applied before and after the practice to reveal the extent to which STEM with arts integrated affects participants' STEM perceptions. The form was finalised by the expert in STEM field except the researcher. A question was directed in the form as 'use the initial letters S-T-E-M to visualise STEM in your minds and remember that architecture field can be integrated into the disciplines of science, technology, engineering and mathematics while you design this imagination'.

2.5. Data analysis

In the analysis of quantitative data, non-parametric tests were used due to the small number of participants as normal distribution would not be expected. Russell and Purcell (2009) suggest that parametric tests should not be used because of the difficulty of normal distribution of data in groups lower than 30 subjects.

In addition, prior to the analysis of the achievement test data, the normality test was performed to identify whether the data were normally distributed or not and to determine the analysis methods to be used. The test results were examined by the Shapiro–Wilk test and the skewness–kurtosis values were also examined. While Shapiro–Wilk statistic value was 0.00, skewness and kurtosis values were not in the range of +1/–1 (Skewness: –1.34, Kurtosis: 1.23). Huck (2012) states that skewness and kurtosis values should range between –1 and + 1 in order for the data to indicate a normal distribution. These values indicated that the data were not distributed normally. Therefore, non-parametric analysis methods were adopted in the data analysis.

In the analysis, Mann–Whitney *U* Test and Wilcoxon Signed Ranks Test were used to look at significance levels, standard deviations and means, eta and Cohen values. $P < 0.05$ significance level was adopted in interpreting the results. In the visualisation practice, a total of 38 visualisations, 19 preliminary practices and 19 final practices were classified and coded in line with the opinions of two experts except the researcher. They were asked to reflect the shape emerged in their mind using the letters S-T-E-M on a paper. The shapes drawn by the students were presented to the experts (in science and archaeology fields). No limit was set for coding for experts. A total of 38 codes were emerged. While these 35 codes were agreed, there were disagreements over 3 codes. In this context, the reliability of the coder was calculated by the formula $(\text{agreement}/(\text{agreement} + \text{disagreement})) * 100$ (Miles & Huberman, 1994). The reliability of the coders for the study was calculated as $(35/35 + 3) * 100 = 92.10\%$. Following an inductive approach, themes were formed from coding.

2.6. Development process and application of STEAM education

The aims of the ancient architecture course, which were framed by the Council of Higher Education and identified by the universities, were considered in determining the achievements of the practice. These are: (1) to be able to enhance terminology related to ancient architecture, (2) to be able to grasp the properties of constructions used in antique architecture, (3) to be able to learn structures belonging to ancient times and (4) to be able to deduce in evaluating archaeological materials by this way (Karamanoglu Mehmetbey University [KMU], 2017). The framework of the study was drawn in the direction of these goals. Within the scope of the study, the researchers and students brainstormed for the STEAM study, which was planned to be carried out within the context of the archaeological education programme, the ancient age architecture course. It was planned to model the architecture of temples in ancient time in accordance with the original using science, technical and engineering knowledge and mathematical calculations of the period. A STEAM activity plan given in this context was established. In creating this plan, the Planning Template for a STEM lesson or unit in Chapter 14 in the ‘STEM Lesson Essential’ book of Vasquez, Sneider and Comer (2013) was inspired (Figure 2).

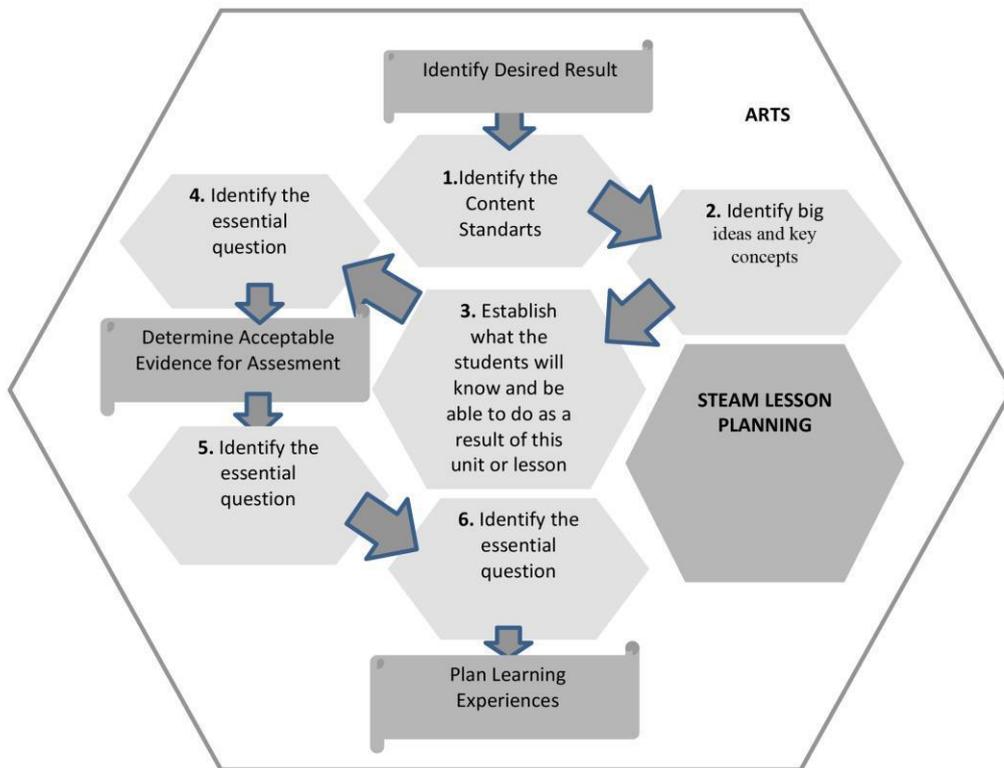


Figure 2. A lesson plan framework for STEAM implementation (Vasquez et al., 2013)

2.6.1. Identify desired result

I. Identify the content standards (Table 3)

Table 3. STEAM outcomes

STEAM disciplines	Objectives
Science	Recognises simple machines and uses them by designing a model
Technology	Knows the technology used in the temple at that time and discovers what the tools developed with this technique
Engineering	Learns by applying which engineering rules should be put together with architectural parts for the robustness of the temple
Arts	Designs the model of the periptelos prostylos temple in 3-D dorr structure and demonstrates their creativity skills by using suitable materials in construction
Mathematics	Knows the mathematical calculations used in the construction of this temple and understands the importance of necessity

ii. Identify big ideas and key concepts

- What is the basic working principle of simple machines used in temple construction?
- What are the tools and equipments used in ancient architecture? What other techniques are used in the architecture?
- How did ancient architecture survive until today? Which engineering knowledge should be known well for a robust structure?
- How should the process be for a creative piece and which skills should be used more?
- What is the role of mathematics in an artwork?

- iii. Establish what the students will know and be able to do as a result of this unit or lesson
 - At the end of STEAM activity, an artistic work is expected to be realised by using science, technology, engineering and mathematics disciplines in the model of an ancient architecture.
- IV. Identify the essential question
 - How are the STEM disciplines utilised in building a temple appropriate for ancient architecture?

2.6.2. Determine acceptable evidence for assessment

- V. Create multiple and ongoing assessment opportunities throughout the learning experiences
 - Simple machine recognition and understanding the working principle (Observation–Achievement Test)
 - Learning ancient tools and equipments (Achievement Test)
 - Understanding the engineering knowledge of ancient architecture (Observation–Achievement Test)
 - Knowing mathematical calculations in ancient architecture (Achievement Test)
 - Forming a creative piece process and modelling (Visualisation practices/Observation)

2.6.3. Plan learning experiences

- VI. Design interdisciplinary learning activities
 - It is inevitable that the STEM disciplines should cooperate closely for the planned activity organised under STEAM. According to the planned STEAM programme, each disciplinary topic is shown in Figure 3. This figure also constitutes the main and subheadings of the steps to be taken during the activity.

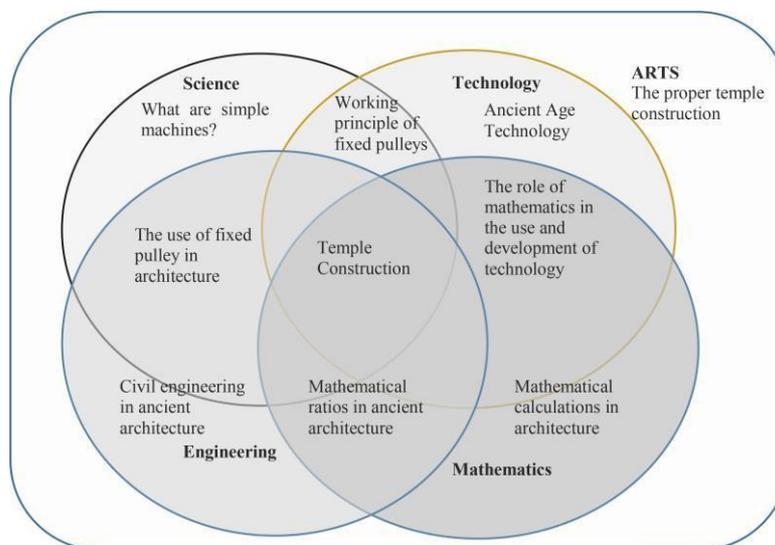


Figure 3. Each disciplinary's topic (Developed by the researcher)

Week 1: The second-year students of the archaeology department were informed that a series of activities within the scope of the implementation in ancient architecture course would be realised and the class was randomly divided into two groups.

Week 2: The STEM academic achievement test was applied to both groups as pre-test and the STEM visualisation practice was applied only to the experimental group.

Week 3: As the result of academic achievement test, one of the two classes, whose achievement levels are similar, was randomly assigned as the experimental group and the other as the control group.

The experimental group students received informative seminars about STEM and STEAM from the researcher. The control group continued to receive the course within the lecture format from the same researcher until the end of the study.

Parallel to the curriculum, four different study groups were formed, consisting of at least five individuals selected randomly for ancient age architecture education.

Week 4, Science: They were asked to gather information about fixed pulleys and their working principles and fixed/compound pulley development practices were realised with LeGo named the 'Mechanical Laboratory' and feedback was given (Figure 4).

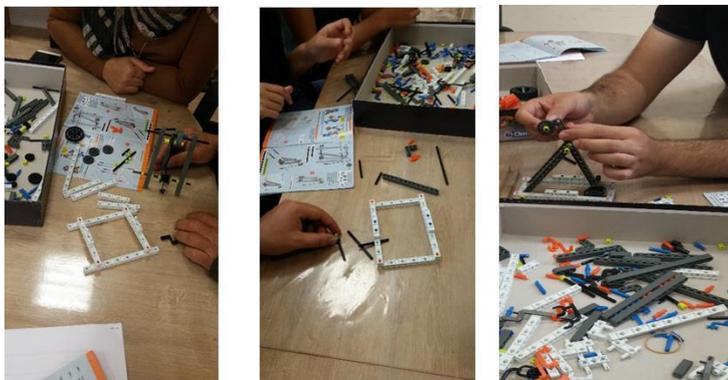


Figure 4. Experimental group working with lego

Week 5, Technology: Ancient age technology was explored by groups.

Week 6, Engineering: Civil engineering in ancient age was investigated and the book entitled 'Archaeology and Civil Engineering Joint Practices' was shared (Toprak et al., 2010).

Week 7, Mathematics: A lesson was given by the expert in the archaeology department regarding the importance of mathematical calculations in architecture and the use of them. The students then made various mathematical calculations on the ground of the temple to be built and understood that some details such as pillars and spaces between them have a fixed ratio.

Week 8, Arts: The students were informed about the architecture of the Parthenon temple on door layout, which is one of the ancient architecture, the Croat of the temple was shared with the groups and then the similar temple construction begun considering the developments in the STEM field at that time. The temple materials were previously prepared for the groups; however, they were not fined for integration. The necessary processes were carried out by the groups (sanding, cutting, pasting, etc.) (Figure 5).



Figure 5. Experimental group working with wood materials for temple

Weeks 9 and 10: Each group continued to build the temple. They were encouraged to use science, technology, engineering and mathematics fields.

Week 11: The completed temples were checked and a person from each group was asked to make a presentation (Figure 6). Lesson presentations of the control group were also completed.



Figure 6. STEAM products

Week 12: The achievement test was applied to both groups as pro-test and the STEM visualisation form was applied again to the experimental group.

Week 15: The retention test was applied to both groups.

During the activities, meetings were conducted with the head of the department to minimise the loss of the subjects and she/he was asked to be sensitive in this respect. It was considered that external validity was provided as such. On the other hand, neither group was perceived to be part of this activity within a study and the researcher delivered the ancient age architecture course in both classes in order to achieve this. The practice was performed in light of circumstances in which internal and external threatening variables were minimised.

3. Findings

In this section, findings obtained in the direction of objectives of the study are included.

3.1. Findings on achievements of experimental and control group students

At the beginning of the study, pre-tests of the achievement test were compared and groups were assigned in order to be able to assign the experimental and control groups neutrally and to reveal the class achievement levels.

Table 4. Group I and Group II pre-test Mann–Whitney-U test

		<i>N</i>	<i>X</i>	<i>ss</i>	<i>Z</i>
The experimental group	Pre-test	19	45.02	12.49	0.90
The control group	Pre-test	19	44.84	15.52	

N = the number of participants, *X* = Mean, *ss* = standard deviation, *z* = statistical value

As seen in Table 4, the result of the test is to form the experimental and control groups and to identify the preliminary information at the same time; the achievement mean score of Group I was 45.02 and that of Group II was 44.84. There was no significant difference between the scores. This

suggests that it is appropriate to assign one of the two groups as an experiment or control group. In this context, Group I was assigned as the experimental group and Group II as the control group.

Table 5. Wilcoxon signed-rank test results on pre-test and post-test achievement scores in the experimental group

Pre-test/post-test	N	Mean Rank	Sum of Ranks	η^2	d	z	p
Positive Rank	13	9.69	126	0.68	0.55	-2.35	0.01*
Negative Rank	4	6.75	27				
Tied	1						

*p < 0.05 was accepted as the significance level

N = the number of participants, η^2 = eta square value, d = Cohen d value, z = statistical value, p = significance level

As seen in Table 5, it was observed that there is a significant relationship between the pre-test and post-test achievement means of the experimental group students. This significance seems to be in favour of the post-test. When the effect value (Cohen) of the practice was examined, it is seen that d = 0.55 while eta squared η^2 = 0.68. According to Cohen (1988), d ≤ 2 values are small, 0.2 < d < 0.8 values are medium and d ≥ 8 values indicate large effect size. The effect size indicates to what extent independent variable or factor explains the total variance in the dependent variable and ranges from 0.00 to 1.00. The values of η^2 at 0.01, 0.06 and 0.14 are interpreted as ‘small’, ‘medium’ and ‘large’ effect sizes, respectively (Buyukozturk, 2008; Cohen, 1988; Pallant, 2005). In this respect, it can be said that the STEM approach implemented in the study has medium effect.

Table 6. Academic achievement mean scores of the experimental group in STEAM disciplines pre-test and post-test

The experimental group	N	Science	Technology	Engineering	Arts	Mathematics	Mean scores	Mean scores
Pre-test	19	11.36	5.05	21.47	14.18	7.15	59.21	2.81
Post-test	19	14.22	9.11	27.77	16.15	9.11	76.36	3.63

Table 6 summarises the achievement mean scores of the experimental group in science, technology, engineering, arts and mathematics fields within the STEAM academic achievement test. Accordingly, there is an increase in favour of the post-test in all fields. When we look at the general mean, it can be said that there is an increase in favour of the post-test. As seen in Table 7, the STEAM pre-implementation mean is 2.81 (59.21/21). The mean obtained from the STEAM post-test is 3.63 (76.36/21). Wilcoxon signed-rank test was used to determine whether there was a significant difference between these point increases.

Table 7. Wilcoxon signed-rank test results of the experimental group for STEAM disciplines pre-test/post-test academic achievement scores

Pre-test/post-test	N	Mean Rank	Sum of Rank	η^2	d	z	p
Science							
Negative Rank	5	4.90	10	0.08	0.61	-1.48	0.13
Positive Rank	9	8.31	41				
Tied	5						
Technology							
Negative Rank	5	9.83	59	0.07	0.89	-2.24	0.02*
Positive Rank	13	8.55	94				
Tied	1						
Engineering							
Negative Rank	5	9.50	38	0.08	0.91	-2.11	0.03*
Positive Rank	13	9.50	133				
Tied	1						

Arts							
Negative Rank	5	7.43	52	0.06	0.62	-1.46	0.14
Positive Rank	9	10.82	119				
Tied	5						
Mathematics							
Negative Rank	3	6.17	43	0.08	0.66	-1.61	0.10
Positive Rank	13	11.64	128				
Tied	3						

* $p < 0.05$ was accepted as the significance level

N = the number of participants, η^2 = eta square value, d = Cohen d value, z = statistical value, p = significance level

As shown in Table 7, the significance between the pre-test and post-test means of five sections of the academic achievement test was examined, and while no significance was observed in science, arts and mathematics fields, there was a significance for technology and engineering fields. When the STEAM approach’s Cohen value on these disciplines is examined, it was seen that $d = 0.61$ and eta squared $\eta^2 = 0.08$ for science, $d = 0.89$ and eta squared $\eta^2 = 0.07$ for technology, $d = 0.91$ and eta squared $\eta^2 = 0.08$ for engineering and $d = 0.66$ and eta squared $\eta^2 = 0.08$ for mathematics. It was observed that the STEAM approach has the greatest impact on engineering and technology disciplines in academic achievement.

Table 8. Wilcoxon signed-rank test results for the control group pre-test/post-test achievement scores

Pre-test/post-test	N	Mean Rank	Sum of Rank	η^2	d	z	p
Positive Rank	9	7.78	70	0.20	0.12	-1.0	0.91
Negative Rank	7	6.75	66				
Tied	3						

$p < 0.05$ was accepted as the significance level

N = the number of participants, η^2 = eta square value, d = Cohen d value, z = statistical value, p = Significance level

As seen in Table 8, there is no significant relationship between the pre-test and post-test achievement means of the control group students. When the effect value (Cohen) was examined, it was observed that $d = 0.12$ and eta squared $\eta^2 = 0.20$. In this regard, it can be said that the lecture style approach has a small effect on the control group.

Table 9. Mann–Whitney- U test results on the post-test achievement scores of the experimental and control groups

Post test	N	Mean Rank	Sum of Rank	z	p
Experimental Gr.	18	24.06	433	-2.74	0.00*
Control Gr	19	14.21	270		

* $p < 0.05$ was accepted as the significance level

N = the number of participants, z = statistical value, p = significance level

As seen in Table 9, the post-test mean score of the experimental group is higher than the post-test mean scores of the control group and the difference between these means is statistically significant.

Table 10. Wilcoxon signed-rank test results for the experimental and control groups post-test and retention test

Groups	Post-test/ Retention test	N	Rank Mean	Sum of Rank	d	z	p
Experimental	Positive Rank	12	7.25	127.50	0.70	-1.97	0.67
	Negative Rank	6	10.63	43.50			
	Tied	1					
Control	Positive Rank	13	8.50	103	0.53	-2.45	0.01*
	Negative Rank	2	7.92	17			
	Tied	4					

* $p < 0.05$ was accepted as the significance level

N = the number of participants, d = Cohen d value, z = statistical value, p = significance level

As shown in Table 10, while there was no significant relationship between the post-test and retention test means of the experimental group, a significance relationship was observed between the post-test and retention test means of the control group. This indicates that education with the STEAM approach is more permanent and achievements are not forgotten immediately.

3.2. Findings related to STEM visualisation practice

It was designed to demonstrate the extent to which the implementation of STEM visualisation applied to the experimental group participants as pre-test and post-test before and after the STEAM practice overlaps with the academic achievement. Prior to the practice applied as pre-test, no explanation or presentation was given about STEM and the visualisation practiced was based on the current knowledge. Post-test was realised 1 week after the practice was completed. As seen in Table 11, 11 (57.86%) of the visual drawn using the letters S-T-E-M in the pre-test appear to be nonsense. Furthermore, codes named as engineering, mathematics, technology, robot, tree trunk, stem cell and achievement are one (5.26%) for each. Two visuals (10.525) were coded as the science activity. When the post-test is examined, it can be said that similar results emerged parallel to the result in the academic test. It was revealed in the post-test by the experts that six (31.59%) visuals were with the technology/tool theme and five (26.33%) visuals were with the engineering theme. Two (10.52%) of the remaining visuals were with the architectural theme and one (5.26%) each was with mathematics, science activity, coding, robot and achievement theme and one was a visual that did not make sense.

Table 11. Codes drawn in pre-test and post-test

Codes	Pre-test		Codes	Post-test	
	f	%		f	%
Engineering	1	5.26	Engineering	5	26.33
Mathematics	1	5.26	Mathematics	1	5.26
Science activity	2	10.52	Science activity	1	5.26
Technology/tools	1	5.26	Tools-equipments	6	31.59
Tree trunk	1	5.26	Coding	1	5.26
Robot	1	5.26	Robot	1	5.26
Stem cell	1	5.26	Architecture	2	10.52
Achievement	1	5.26	Achievement	1	5.26
No sense	11	57.86	No sense	1	5.26
Total	19	100	Total	19	100

Some images in the pre-test and post-test are shown in Figures 7 and 8.

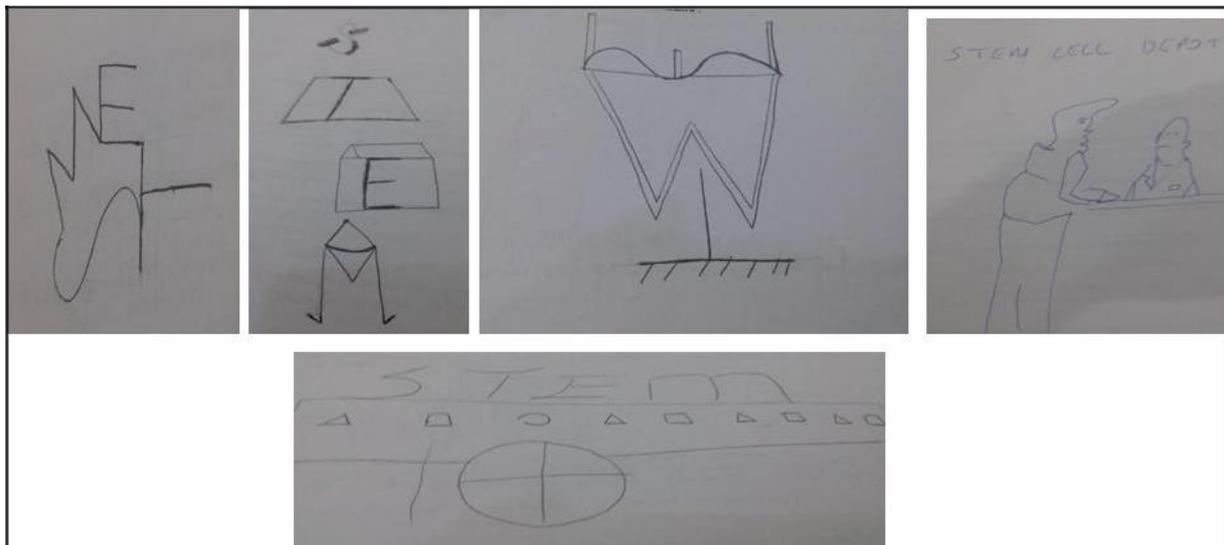


Figure 7. Some of the pre-test visualisation practices

The images in Figure 7 show that STEM is not fully understood or misunderstood

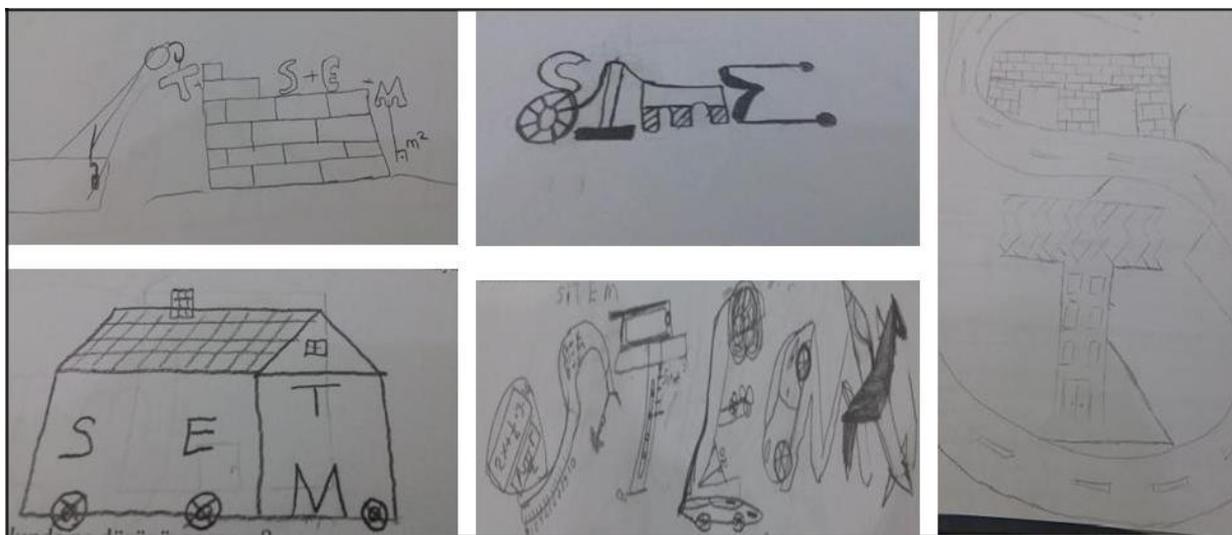


Figure 8. Some of the post-test visualisation practices

Images in Figure 8 indicate that STEM seems to recall technology/tool and engineering themes more. It is clear that STEAM education was influential in the foreground of these themes in visualisation practices. It can be said that especially utilising engineering and technology disciplines more than other STEM disciplines during the study was effective in visualisation practice. It is also seen from the table that it has an effect on arts. As a result, outcomes obtained in visualisation practices are parallel to achievements of disciplines in the academic achievement test.

4. Conclusion and discussion

This research is an original study based on the mixed method in the context of practices from STEM to STEAM in the literature. In particular, it was considered that this study contributes to the literature in terms of several aspects such as implementing the STEAM approach into the archaeology field, designing an experimental study to reveal its effects on academic achievement, observing changes in

STEM perceptions with visualisation practices and illuminating its relationship with academic achievement. Although it is considered that the disciplines of arts and STEM are separate from each other, it can be said that they are complementary and supporting each other (Sousa & Pilecki, 2013). Some studies integrating STEM into arts appear in the literature (Guyotte et al., 2015; Miller & Knezek, 2013; Yakman, 2008). In these studies, it is reported that STEM curriculums integrated in the field of arts not only increase students' academic achievements in STEM fields but also contribute to their artistic abilities (Sousa & Pilecki, 2013). In this present study, a STEAM programme was developed considering the curriculum of the ancient architecture course framed by CHE and identified by the universities, which is included in the undergraduate programme of archaeology, and the experimental activity was realised in line with this programme. It was revealed that the experimental STEAM activity carried out during the first stage of the study based on the mixed design has a positive effect on the academic achievements of the students. In particular, it was observed that the STEAM activity provides more contribution to the students in engineering and technology fields in STEM disciplines. This result is parallel to some studies in the literature (Baker, 2014; Kwon, Nam & Lee, 2012; Lee & Park, 2010). It is possible that the higher effect value of the STEM activity on engineering and technology fields is due to the activity realised, because in the process of designing an ancient age temple, engineering and technological information were utilised more effectively. In addition, achievement in arts, mathematics and science is also a matter of concern. Despite the intensive use of mathematical calculations in particular, the low level of achievement in the mathematics discipline can be attributed to the fact that the students of the archaeology department came from the social field within the university exam (OSYM [Student Selection and Placement Center], 2016). The 'Imagine STEM' practice carried out before and after the study was realised to determine the extent to which the STEM activity influenced participants' STEM understanding. It is emphasised in the literature that the integration of arts and science enables students to use more of their minds using different cognitive skills (Pollock et al., 2017). The drawings in the pre-test applied to the experimental group students prior to the activity revealed a perception of STEM which is either meaningless or misidentified. On the contrary, after the activity, it was identified that the themes that emerged in the post-test drawings were from engineering, technology and architectural field. This result is in line with the result obtained at the end of the academic achievement test. At the same time, this result supports Henriksen's (2014) view that STEAM ought to become a fundamental paradigm in the creative and artistic teaching and learning of science. By integrating arts into STEM, it was shown that STEAM needs to be accelerated in other arts fields, especially its contribution into career development in engineering and technology fields and the increase in the quality of artistic products revealed. There are already suggestions to this in the literature (Henrkisen et al., 2015). STEAM practices are also important in terms of drawing out students who are not particularly interested in mathematics and science (Vanasupa, 2012).

In the research, the integration of architectural art into STEM in archaeology, which is a social field, was realised. Perhaps, one of the weakest aspects of the study is that the participants are studying in a social field and they do not have great interests in STEM fields. There were also some deficiencies to continue with the activities, but the parts they missed afterwards were compensated out of the course. In future studies, for example, disciplines such as music and art teaching can be integrated into the STEM. The impact of these studies on participants' STEM career interests and STEM attitudes can also be investigated.

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