Understanding Ancient Greek Civilizations: A STEAM Teaching Perspective

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Abstract

The aim of this research is to suggest a didactic approach as to how students comprehend the growth and the activities of the two most well-known Ancient Greek civilizations (i.e. the Mycenaean and the Cycladic). The teaching approach is based on STEM perspective, the use of several digital technologies, as well as several learning theories. Digital technologies help students delve into the process of scientific discovery. The degree of new technology and STEM – based didactic approach appealing to students is evaluated through questionnaires. In particular, in our survey, 115 students participated and the questionnaires distributed to four schools of Volos and Veria Greece region. The Research was carried out with the consensus of their parents. According to our results, students expressed great interest in STEM activities that they were exposed to. Moreover, they expressed high interest in the integration of a classic history lesson with new technologies and they developed the ability to create simulations of ancient civilization activities. Furthermore, our work is focusing on issues regarding the process and efficiency, through the use, of an interactive time – line robotic car, which will be used to categorize historical events into periods on a timeline.

Keywords: STEAM, Minoan culture, Cycladic culture, Learning and Innovation

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Introduction

Nowadays, since education is inextricably linked to developments in other sectors such as the economy and society, new, innovative teaching methods and practices need to emerge. The field of education is an important sector for humanity and the need for evolving its methods is vital. This development takes place through the preparation of students for the future, with the help of the STEAM approach. Proof of its resonance is the fact that by order of former US President, the US Department of Education set up a special office for the expansion of STEAM, while a lot of money was invested in high quality innovative technologies.

The present study deals with the connection of sciences through Technological Means. That is, an attempt to achieve unification between didactic fields, which aims to contribute to the development of critical thought for children, as well as prepare them for the demands of the 21st century. The majority of educators realize that one fundamental issue schools face today, is the fragmented approach of knowledge, and skills from different disciplines, and the fact that students cannot often manage to solve a problem, since they do not know the wider framework in which problems are integrated (Frykholm & Glasson, 2005; Wicklein& Schell, 1995). STEAM teaching and learning is based on research and is supported by the digitization of students' assignments. As a result, students are given the opportunity to easily transfer previous knowledge they have acquired, while dealing with creative new problems. Meanwhile, their successful integration stimulates creativity, curiosity and teamwork (Roberts, 2012).

In addition, an attempt is made to evolve the approach and to introduce the concept of social context in the learning of History, building skills that emphasize exposure to authentic problems, thus making teaching more interesting by enriching them with the skills of logic, active participation and creative and critical thinking. Therefore, theories such as behaviorism, which characterize the traditional teaching methods, are no longer supported, and a big emphasis is given on the perceptions of the subjects, as well as the social and cultural frame in which they are developed. At the same time, the teaching environment, as well as the potential for formation of cooperative learning teams of the didactic objects through exploratory activities, is worth mentioning. Teachers and their students work and collaborate better within the framework in which STEM educational efforts are supported.

Additionally, in this work, authors present a systematic way to examine the motives behind the formation of an authentic learning environment, in which students understand historical phenomena, not by just reading from the sources, but through their observation to follow a more critical point of view. Throughout this process, students formulate questions, comment, analyze

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and deduct conclusions regarding the causes and effects of historical events. To this end, the innate logic of the connection of parts in a bigger scale is recovered, not cumulatively but via the creation of a new cognitive area. The ultimate goal of the above is to make it clear that the teaching of history through STEAM aims at achieving a common goal of a good purpose, which is none other than connecting with our common heritage through science, technology, art, engineering and mathematics.

Background definitions

Cycladic Civilization

One of the oldest civilizations in Europe evolved in Cyclades Islands during the 3rd and 2nd millennium BC, i.e. in the Bronze Age. Their particularly privileged geographical location consisted as one of the main reasons that contributed to this. Actually, the islands of the Cyclades are a kind of natural bridge between Europe and Asia, Mainland Greece and Crete. In the 3rd millennium BC, the ships of the Cycladic islands that dominate the Aegean, along with the products of the East Asia, transfer also ideas, technical knowledge, and religious perceptions to Europe.

Mycenaean Civilization

The Mycenaean Civilization was the first Greek civilization of the Late Bronze Age, which evolved during the period 1600-1100 BC., mainly in central and southern mainland Greece. The Mycenaean Civilization is identified with the last period of Greek Culture, the Late Helladic Civilization.

STEAM Approach

There is a discussion in the educational community about STEM and STEAM approach of cognitive disciplines, regarding the need for the integration of humanities and Art in general. Also, according to the study of (Ghanbari, 2015), it is mentioned that arts are suitable to coexist with the other four STEM scientific pillars. Through the development of -A- (in STEAM) a possibility is given for the growth of creativity, the increase of empathy and a better understanding of the human factor among scientists. STEAM can be considered as an educational approach for the teaching and learning of History lessons, through the application of a methodological approach discipline, not in a cumulative way but via interaction, so that we can be led to a new discipline, as a result of this reciprocal correlation.

Learning using the STEAM approaches

Learning and Innovation

In order to diffuse innovation into contemporary Schools, new teaching methods, based on technological means and methodologies need to be proposed. Educational sciences indicate us of how to create learning centers, though, which, trainees will understand the existing need for learning both adaptability and innovation. Many countries have progressed on the studying of sciences, which they published on Research Council's How People Learn in the USA (Brown, & Cocking, 2000). In fact, the issues that were addressed by the experts of most member countries, regarding the learning sciences, are deemed quite important (Kozma, 2003). Stakeholders (i.e. the people who define educational policy in countries) consider that they have transitioned from capital economy to knowledge economy. Practically, this means that knowledge produces innovation. However, in order innovation to be produced from knowledge, students need to be trained in innovative abilities and dimensions of computational thinking and STEAM.

Therefore, an important issue that arises is the outline of an increasingly specific vision for the future of learning. The STEAM approach, as discussed below, combines innovation with teaching and enables students to generate and apply new ideas and practices, as well as problem-solving skills for History lessons.

Problem-based learning

Problem – based learning (PBL) is a learning process in which the student faces a problem, which challenges him to overcome mentally obstacles and reach a solution. In our applied teaching scenario, students apply rules and principles already conquered and following construct new knowledge that allow them to solve a given problem, via collaboration with the classmates. Within the PBL learning framework, the problem definition plays an important role, while emphasis is also given in the solution process. The type and degree of problem construction (i.e. strongly or weakly structured), constitutes its basic characteristics. Different types of problems are decision – making problems, dilemmas, design problems (which require modelling), and solution – diagnosis problems.

PBL, which focuses on the solving process, is usually quick and the students participate in the formation of the goals. The role of the educator is discreet and interferes only when needed. In their work, Savin-Baden & Major (2004) suggested a model comprised of seven phases:

1. Clarification of concepts,
2. Definition and demarcation of the problem,
3. Discussion and analysis of the problem,
4. Discovery of possible solutions/ explanations,
5. Definition of work regarding the learning goals
6. Search for the solution
7. Composition of results/ solutions - reflection and evaluation

Technical Steps

Within the process of connecting the theoretical framework with the understanding of the two ancient civilizations (i.e. Mycenaean, Cycladic), students are asked to respond to certain problems such as that of the Cycladic that faced the challenge of building masterpieces of Marble Figurines.

History teachers help students think of these creations as a solution to a problem and then deepen by asking students:

What were the technical skills that had to be faced to create the Figurines?

Some of the challenges that Cyclades would face include calculating the dimensions of the marbles, transporting them from one point to the other and assemble them to achieve the masterpiece. The above information, as integrated to the teaching process, is related to the process or rediscovery and innovation, which is the fundamental concept of the interdisciplinary approach. A similar teaching approach is realized for the *Cyclopean Walls* during the Mycenaean era and the monumental palaces they built. For the purposes of our study, students are provided with laptops and a 3D printer, to work with the artifacts needed for the 3 history lessons. Students are involved in a goal – driven activity that is in authentic context with students' self – efficacy control, in terms of its purpose and application knowledge acquired.

Methodology

For our intervention, we followed the exploratory teaching method and the goals that we set are as follows:

- Help students understand the value of dummies of the Cycladic era and the floor plan of a Mycenaean palace.
- Design virtual tools and test them.
- Use technology means to explain various technological phenomena of other eras

In **Table 1**, we give the prerequisite knowledge for the parts of our applied teaching scenario, such as: *basic computer skills, skills to solve motion equations and model construction.* The intervention took place in Magnesia (central Greece) and Imathia (North-West Greece) prefectures, for high school students. The teachers involved, collaborated with the authors of this article for further help and support at all teaching levels. After the intervention, students completed an anonymous questionnaire, the answers of which is analyzed below. We used appropriate software to construct a timeline regarding historical events (**Figure 8**).

Our study is based on 115 in total, randomly selected, students from both prefectures, 54 of which are boys (47%) and 61 girls (53%). The intervention took place during the *Technology class,* with the participation of both History and Computer Science / Technology teachers. Initially, students were given a questionnaire to answer regarding their initial attitude and views for the history course. According to their answers, the girls in a percentage of 82%, showed to be familiar with the ideas for that course. On the other hand, the boys' percentage is 43%. However, after the intervention, the boys' percentage, reflecting positive view of the course, almost doubled and reached 81%. Following, the girls' percentage increased to 93%. According to these encouraging percentages, we believe that the most important finding of this study focuses on the students' following the problem - solving process, enhanced with technological means, during learning about important historical events. Thus, they understood deeply a theoretical subject, via STEM methodology.

Teaching scenario

In this section, we present the pillars of our applied teaching scenario, which focuses on the section of "Mycenaean and Cycladic Civilization". The scenario concerns four High Schools, two in Magnesia and two in Imathia region.

Table1. The parts of the Teaching Scenario

The parts of the Scenario	Analysis
Title	Mycenaean - Cycladic culture
Application class	1st grade of Gymnasium
Cognitive areas involved	History, Mathematics, Computers, Technology
Prerequisite knowledge	Computer skills, solving simple equations, proportions and model construction

Guidelines

A group of students will create the timeline of the events, using the online software https://time.graphics/editor. Other group will construct the timeline, using materials and following the instruction we present below. For that purpose, students instructed to cut a large piece of cardboard, on which they create the timeline, as depicted in **Figure 3**. On the right side of the lane, historical events are shown, and on the left side, four historical milestones are present. For each historical era, we placed a representative temple model to represent that period. The robotic car, programmed by students, reaches each of these models and park, as an indication that students reply correctly to a question, concerning a certain historical event. Additionally, students program three traffic lights (i.e. red, orange, green LEDs) within a virtual Arduino environment. The LEDs work as indicators as to whether the robotic vehicle stops or passes to the next historic period. **Figures 1** and **2**, give a representative snapshot of the coding environment.

As a prerequisite knowledge, we show students how to simulate a traffic light condition, using the on line Arduino simulation environment of Tinker CAD (available at: http://www.tinkercad.com). According to **Figure 2** students created a traffic light circuit with three distinct states, each of which expressed by a LED. Students use the embedded optical programming language of Tinker CAD, which includes the majority of Scratch4Arduino blocks.

```
void setup()
{
  pinMode(9, OUTPUT);
  pinMode(A0, INPUT);
  pinMode(6, OUTPUT);
  pinMode(5, OUTPUT);
  pinMode(3, OUTPUT);
}

void loop()
{
  analogWrite(9, 1023);

  if (analogRead(A0) >= 512) {
    analogWrite(9, 1023);
    delay(5000); // Wait for 5000 millisecond(s)
    analogWrite(9, 0);
    delay(1000); // Wait for 1000 millisecond(s)
    analogWrite(6, 1023);
    delay(3000); // Wait for 3000 millisecond(s)
    analogWrite(6, 0);
    delay(1000); // Wait for 1000 millisecond(s)
    analogWrite(5, 1023);
    delay(15000); // Wait for 15000 millisecond(s)
    analogWrite(5, 0);
    delay(1000); // Wait for 1000 millisecond(s)
  }

  analogWrite(3, 0);
```

Figure1. Arduino IDE Coding

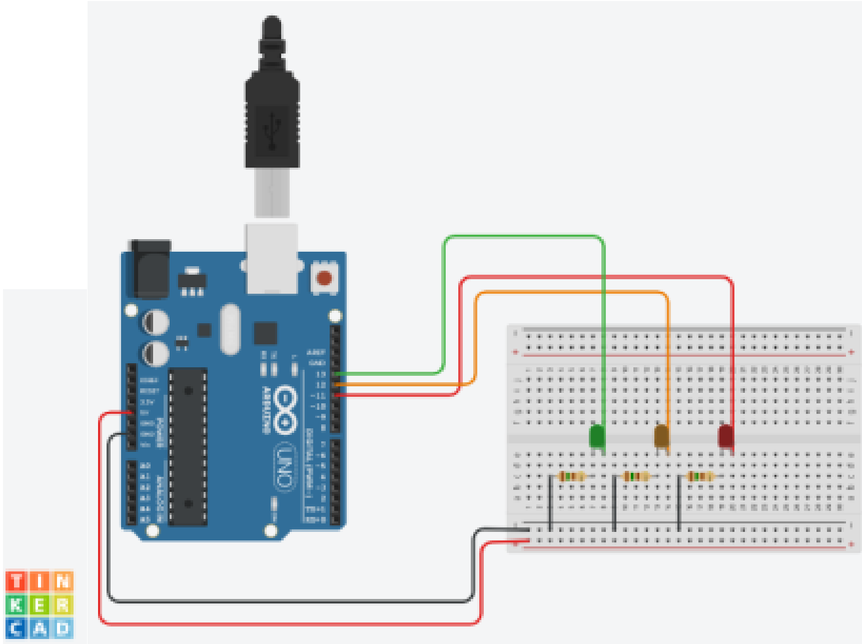

Figure 2. Arduino Circuit and Optical Programming

In order to facilitate the robot's car directed movement, we place an insulating tape. The color of the tape changes each time we want to direct the car to visit a specific historic period.

Figure 3. Timeline construction result

Following, we show students how to install Lego EV3 programming environment (**Figure 4**) (available at: https://education.lego.com/en-us/downloads/mindstorms-ev3/software). Each involved teacher prepares a group of students regarding EV3 programming, using simple tutorials. These teachers are then responsible to help the students involved in this research, to conquer the knowledge required and apply for the teaching scenario.

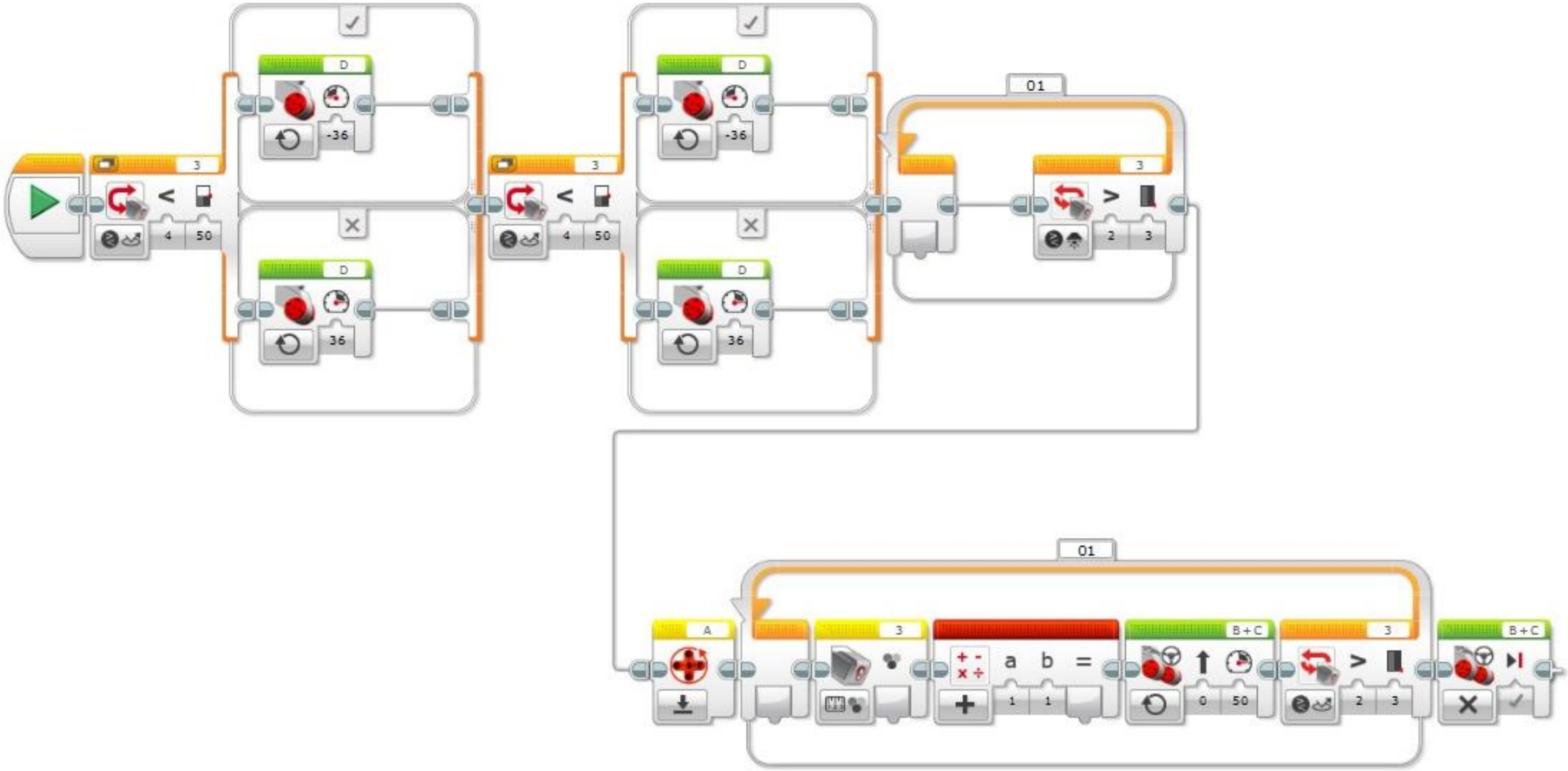

Figure 4. Ev3 Coding routines

We split 115 students in two groups, which alternates between the task of the floor plan construction and the software development, regarding the robot's control behavior. For the construction phase, teachers provided the students with all necessary materials (i.e. cardboards, rulers, glue, papers etc.) and tutorial. For the construction process, we use rice cardboards to print the floor plan, as **Figure 5** depicts.

Figure 5. Rice Cardboard

Additionally, metric scale ruler and diabetes (**Figures 6** and **7**) are used for precision in geometrical shapes

Figure 6. Metric Scale Ruler

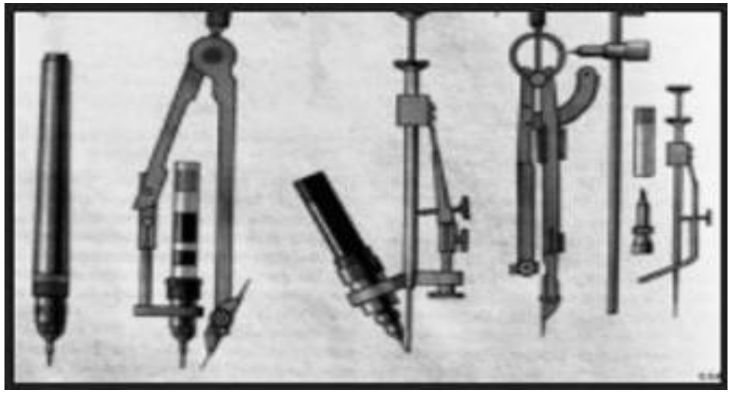

Figure 7. Diabetes for geometrical shapes

In parallel with the construction team, the second team works with the software and especially with 3D modeling in Free Cad (available at: https://www.freecadweb.org/), to build the historical models, necessary for the STEM teaching scenario

Teaching course

The scenario follows the exploratory approach with the following phases:

1. **Involvement - Orientation:** Students are provided with Mycenaean images, as examples. We ask them to answer questions related to the usage of metals as compared with today. We also ask students to speculate whether Mycenaean technology was innovative and if we some of our daily devices could be based on that historian technology means. The duration of this phase is about 10 minutes.
2. **Conceptualization and recognition of prior knowledge:** At this step, students' prior knowledge is recalled, as a prerequisite of the previous phase. Then the teacher asks the following questions: a) How models constructed with such precision in the old times, without the sophisticated technology? b) What was the metals' processing procedure without sophisticated technology? The duration of this state is 10 minutes.
3. **Research - Experimentation:** At this phase, students using a worksheet, which the teacher considers it to be a tool to guide their exploration, study the research questions that have been asked in the previous stage.
4. **Interpretation of results**: This is the most important phase, which includes the individual stages of clarification and exchange of ideas among students, new knowledge construction and conclusions drawing. In particular, students examine to what extend research questions are verified.
5. **Discussion - Reflection:** The findings and results of each group of students in the plenary are presented after the implementation of the Worksheet. In addition, students are asked to reflect on how their original ideas have changed (metacognition), with questions asked by the teacher.

Activities

Students are divided into groups, each of which undertakes a part of the project. The study area focuses on a range from 3000 B.C. to 1200 B.C. and students create a historical timeline, using the proposed free software tool. Therefore, each team focuses on four important historical events and, finally, they work together to evaluate the events and record the most important ones on the timeline. Afterwards, students are given a floor plan of a palace, and work with it to answer the following:

1. Does the palace construction supports any pattern?
2. Are the materials used, environmental friendly and to what extend?
3. Can a palace, like the one you are given as a model, could be have been build today?

Finally, students were asked to create a floor plan, mimicking the structure of a model palace. With the following, activities, teachers trigger students to think whether such palace could be functional today, if someone would built it within a contemporary environment.

Activity 1

In this first activity, students should be able to construct a chronological timeline, based on several criteria.

A) Trigger

Firstly, the teacher asks the students to be familiar with the functionality of the software: https://time.graphics/editor

B) Assumptions - experimentation

Students placed four events of the Mycenaean period, in chronological order, and according to the following criteria:

1. Significance of the facts
2. Whether these events influenced the attitudes and perceptions of the people of the time
3. To what extent these events affected technological development. For example:
    - Henry Schliemann
    - First Mycenaean bands
    - Cyclopean walls
    - Linear B'

They process the timeline as well as the interactive time-car that will move according to the timeline, as **Figure 8** depicts.

C) Formulation of theory

We explain the events of the Mycenaean era with the help of videos and pictures.

D) Continuous control

Subsequently, the students experiment on:

- moving the time car to the period of the 3rd stop events and
- turning on the LEDs (using of Computational Thinking)
- If LEDs light up, the coding is verified.

E) Evaluation - Reflection

We observe, if they have understood the facts, to what extend they cooperate and at the same time if they can justify their answers. The duration of this activity is estimated to 2 hours.

Activity 2

In the second activity, teachers ask the first group of students to draw a floor plan structure of a palace, using Free CAD (**Figure 9**). A second student group draws a Cycladic figurine model, applying geometry knowledge to properly program design parameters. Then both teams print their designs on a 3D printed. The printing process took place after intervention phases.

A) Trigger

One group observes the floor plans of the Mycenaean palace while the other group observes the model of the figurine of Cycladic Art.

B) Assumptions – experimentation

The team that uses the computer application edits the Free Cad software and customize its functionalities. On the other hand, the team that constructs the plan, using artifacts, works with rulers, compasses, diabetes and meters.

C) Formulation of theory

During this section, teachers explain the Cycladic and Mycenaean culture and way of living, what the figurines usually represented, as well as, what a Mycenaean palace was. **Figures 10** and **11** used for facilitating teaching process.

D) Continuous control

The student groups experiment on creating 3D drawings based on the drawings given to them in a previous phase.

E) Evaluation - Reflection

In this stage, we observe, whether students understand all facts, as well as to what extend they processed the information. In parallel, we discuss what steps the follow to justify their answers. The activity's duration is four hours.

Figure 8. Software for Timeline monitoring

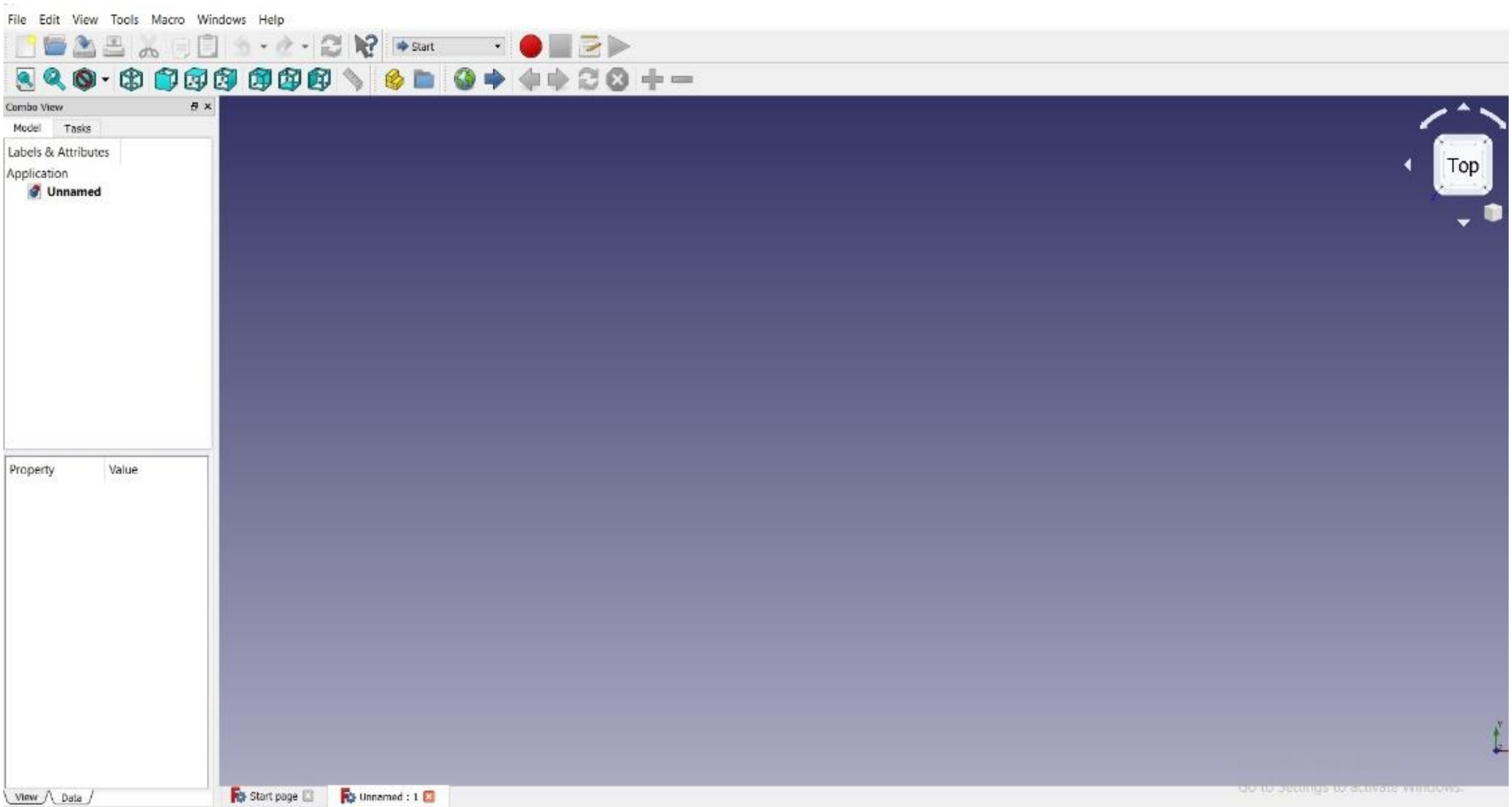

Figure 9. Free Cad working canvas

Figure 10. Figurine

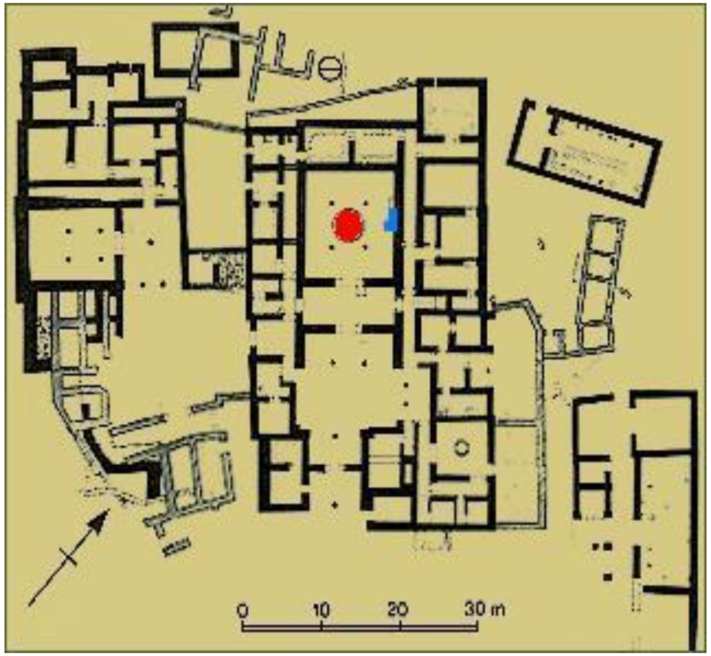

Figure 11. Mycenaean palace top view

Results and Discussion

In this section, we present our findings. Students are satisfied by the teaching intervention, and facilitate the linking of a theoretical subject, such as History, with STEM technology artifacts and believe that they conquered knowledge more efficiently. In this paper, we tried to connect history teaching with the process of scientific discovery. In the heart of this process, student work in teams and use computerized tools to draw conclusions regarding historical civilizations. Students not only need engagement with critical thought and investigation, but also the creation of a proper, original and authentic learning environment where the connection of the students with historical sources and natural phenomena transcends the simple skills of reading or observation transitioning to the field of interaction with them, through the utilization of physical objects and digital elements. This may be partly because teachers may not have knowledge of the content of science and indicate that they are not prepared to teach using the STEM methodology (Akerson, 2004).

The results of this study is based on a STEM teaching approach, enhancing a theoretical subject with computerized tools. During the offered activities, students work in groups, collaborate and get involved with physical computing and programming skills. As a product of time, technology progresses constantly and provides the opportunity for improvement in teaching and learning from the first years (Donohue, 2015).As a result, students are given the ability to constantly seek information and better shape their knowledge. Such experiences lead students to think deeply and with critical thinking. Is it therefore clear that *engineering* approach is of major importance, for the STEM epistemology? According to (Shirey, 2017), this approach, is referenced as *Engineering Pedagogy*.

According to Shirey (Shirey et. al, 2015), *Engineering* can be divided into *Engineering content* and *Engineering design*. The content dimension of Engineering derives from the physical sciences incision (i.e. Physics, Biology, Chemistry, etc.) and Mathematics, which provides the tools an engineer can use, in order to design solutions for specific problems. The *Engineering design* is linked to the implementation of a repetitive plan where the problem will be defined, ideas for its solution will arise, and afterwards a systematic implementation method with checking and improvements will exist. This process is also considered to be a didactic design of the "problem solution" type (Moore, 2014).To summarize, the epistemology engineering pedagogy, relates to the creation of effective and reliable artifacts (i.e. machines and physical computing components), the pedagogical knowledge of STEM content of objects, and the implementation of such knowledge via interdisciplinary didactic designs. Experience with data measurement and analysis provide the fundamentals for complicated thought and problem solving skills (Gelman, Brenneman, MacDonald, &Roman, 2010). After the teaching intervention, the vast majority of students enriched their knowledge regarding the Mycenaean civilization. They worked with the models provided by teachers, studied and experimented with the figurines, and familiarized themselves with the way they made back in their era.

Our paper focuses on research efforts regarding as to what extent STEM curriculum can promote learning and critical thinking development. Prior to distributing questionnaires to students, both the principals and teachers were informed about the research purposes. All participants exhibited great willingness to support this study. At the same time, oral instructions and clarification information shared with them. Before the intervention, a relevant presentation was given to the teachers, who are involved during teaching scenarios, in order to inform them about the methodology. This was done for both Volos and Imathia are schools. The questionnaires were given before and after the intervention, for comparison reasons. As far as the results robustness is concerned, a comparison is made between student groups, before and after the intervention. Before the intervention, students of both the experimental group and the control group, filled the questionnaire. After the intervention, students answered same questionnaire, in order the research group to compare results. Finally, students' group distribution was based on a random selection criterion, to ensure statistically robust results.

In **Figure 12**, we depict results, based on a Likert scale, regarding the students' believes as to what extend STEAM approach helped them better understand the taught course and grasp all necessary knowledge. The student majority believe that new STEAM and ICT techniques better facilitated them in understanding and combine course's ideas. This is also justified by the enthusiasm they showed during their participation in the experimental process, scenarios and activities. However, a 13% of the students disagree with the process, either because they are not adjusted to the interdisciplinary STEM process, or because they do not feel quite familiar using ICT tools. Moreover, a 40% percent of the students, neither agree nor disagree, because they feel confused to some extend as far as the interdisciplinary approach is concerned, for a joint theoretical and computerized teaching approach.

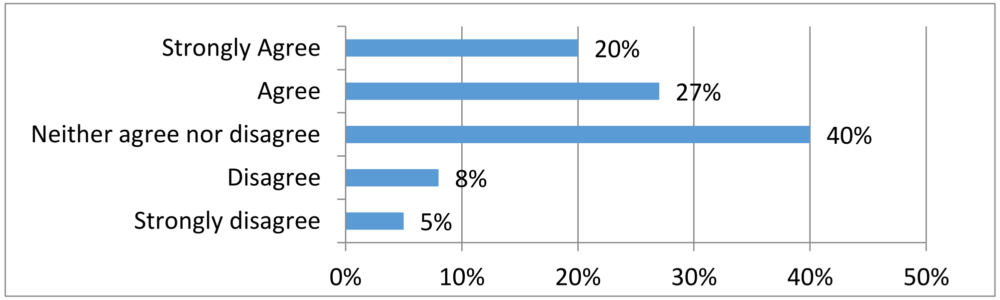

Figure 12. STEAM approach helped you understand better the course

Following, in **Figure 13** we depict student answers regarding which activities helped them most in understanding the lessons. From the results, the majority of students show a positive attitude towards the combination of mixed theoretical with science practices teaching and construction. Additionally, students realize the value of critical thinking to better understand a theoretical subject and draw conclusions. However, a 5% of students state that technology does not help them really. This attitude is interpreted by their teachers as skepticism due to them not being fully familiar with new technologies.

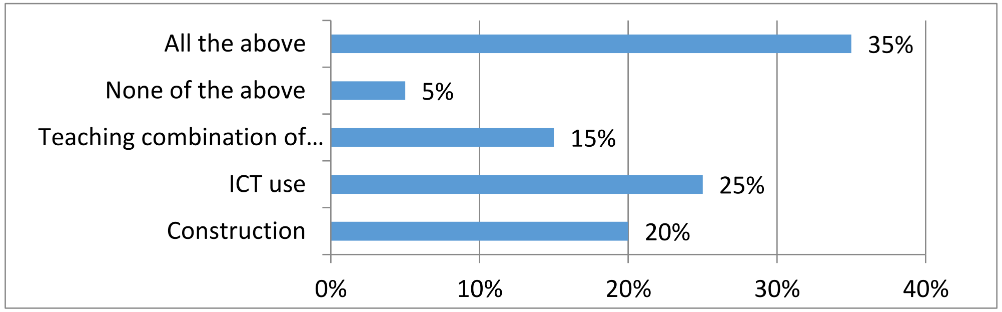

Figure 13. Which part of the activities helped you the most in understanding the lesson?

Figure 14, depicts an overall students' attitude towards STEAM process and practices during their lesson. It depicts to what extent, as a whole, students have or not difficulties in applying new technology and combine information in a critical way, to understand their lessons.

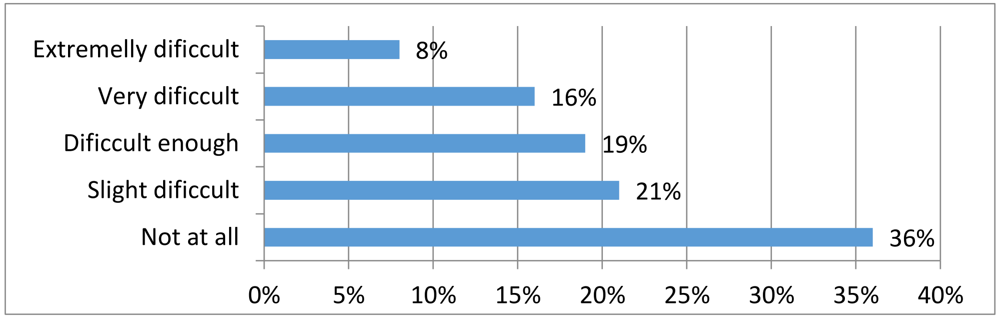

Figure 14. Did you have any difficulties in understanding the activities?

According to the previous graphs, it is expected that one out three students to not have any difficulties in understanding the teaching activities, nor in participating in the programming and construction of the artifacts. However, around 20% expresses cautious optimism due to the fact that STEM interdisciplinary practices are unknown yet to them. The participating teachers, believe that most students find difficult to adjust to using ICT during a history lesson, as combined with the difficulties in programming. However, overall students expressed their optimism and willingness to participate in similar activities in the future. This states that STEAM practices is welcome to the majority of student community.

Conclusions

Our results are in line with the results of Xenakis et. all (2019), regarding the use of STEAM and educational robotics to enhance students' critical thinking in K-12 education. The students covered all theoretical aspects of their lesson by involving themselves in construction and programming phases. Several scientists suggested that the perspective of knowledge building (Scardamalia & Bereiter, 2012) may explain learning in Problem - based learning (PBL). In fact, problem solving is scientifically linked to constructive epistemology, since it considers that trainees connect their experience with the structure of concepts, while at the same time, high level abilities such as crucial thinking and logical justification are favored (Jonnasen, 2000; Jonnasen& Hung, 2008).

PBL is strong as partial strategy, mainly for demonstrating the implementation framework in the first levels of a curriculum. In order to learn how to provide solution to real problems in the area of engineering, as well as to other science fields, PBL seems to be a suitable choice. Therefore, the integration of STEAM in education, can upgrade the quality of knowledge transfer, as provided by teachers to students. It may increase students' level of understanding and improve learning outcomes. It is a modern way to combine the offered knowledge with the needs - requirements of everyday life, so that students can understand the value of the knowledge provided and harmonize it with the requirements of everyday life.

In conclusion, the problem-solving method is relatively more efficient than traditional teaching and more flexible in the application of knowledge. Nonetheless, opinions that consider it to be inadequate and should be complemented with problem solving activities in a smaller time scale, also exist. Our paper proposition highlight, through results, the value of PBL and STEAM enhanced teaching for interdisciplinary teaching process.

References

Akerson, V. L., & Abd-El-Khalick, F. (2003). Teaching elements of nature of science: A yearlong case study of a fourth grade teacher. *Journal of Research in Science Teaching, 40*(10), 1025 – 1049.

Barrows, H. S. (1998). The essentials of problem-based learning. *Journal of Dental Education, 62*(9), 630–633.

Bereiter, C. (2002). *Education and mind in the knowledge age*. Mahwah, NJ: Lawrence Erlbaum Associates.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.) (2000). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.

Burgess, L., & Street, D., (2004). *Optimal designs for asymmetric choice experiments*. CenSoC Working Paper, No. 04-004. University of Technology, Sydney, Australia.

Bybee, R.W., Trowbridge, L.W., & Powell, J.C. (2008).*Teaching Secondary School Science: Strategies for Developing Scientific Literacy*. New Jersey: Merrill.

Carnegie Foundation (2013). *50-State Scan of Course Credit Policies*. Stanford, CA: Carnegie Foundation for the Advancement of Teaching.

Chalufour, I., & Worth, K. (2004). *Building structures with young children*. St. Paul, Minnesota: Redleaf Press.

Clements, D. H., Sarama, J., & DiBiase, A.-M. (Eds.). (2004). *Engaging young children in mathematics: Standards for early childhood mathematics education*. Mahwah, NJ: Lawrence Erlbaum Associates.

Clements, D. H., Sarama, J., & Germeroth, C. (2016). Learning executive function and early mathematics: Directions of causal relations. *Early Childhood Research Quarterly, 36*, 79–90. https://doi.org/10.1016/j.ecresq.2015.12.009

Donohue, J.W. Jr. (2015) - books.google.com

Ehrlich, H. L. (1998). Geomicrobiology: its significance for geology. *Earth Science Reviews, 45*(1-2), 45-60. https://doi.org/10.1016/S0012-8252(98)00034-8

Engeström, Y., & Sannino, A. (2012). Whatever happened to process theories of learning? Learning. *Culture and Social Interaction, 1*(1), 45–56.

Frykholm, J., & Glasson, G. (2005). Connecting science and mathematics instruction: Pedagogical context knowledge for teachers. *School Science and Mathematics, 105*(3), 127-141.

Gelman, R., Brenneman, K., Macdonald, G., & Roman, M. (2010*). Preschool pathways to science: Facilitating scientific ways of doing, thinking, communicating and knowing about science*. Baltimore, MD: Brookes Publishing.

Ghanbari, S. (2015). Learning across disciplines: A collective case study of two university programs that integrate the arts with STEM. *International Journal of Education & the Arts, 16*(7). Retrieved from http://www.ijea.org/v16n7/.

Hestenes, D. (1999). The scientific method. *American Journal of Physics, 67*, 273-276.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*(3), 235–266.

Ho, A. V. (2012). Computation and computational thinking. *Computer Journal*, *55*(7), 832 – 835.

Hußmann, S., Schacht, F., & Schindler, M. (2019). Tracing conceptual development in mathematics: epistemology of webs of reasons. *Mathematics Education Research Journal, 31*(2), 133-149.

Hung, W. (2009).The 9-step process for designing PBL problems: Application of the 3C3R model. *Educational Research Review, 4*(2), 118–141.

Hung, W., Jonassen, D. H., & Liu, R. (2008). Problem-Based Learning. In J. M. Spector, J. G. van Merrienboer, M. D., Merrill, & M. Driscoll (Eds.), *Handbook of Research on Educational Communications and Technology* (3 ed., pp. 485-506). Mahwah, NJ: Erlbaum.

Jona, K., Wilensky, U., Trouille, L., Horn, M. S., Orton, K., Weintrop, D., & Beheshti, E. (2014). *Embedding computational thinking in science, technology, engineering, and math (CT-STEM).* In future directions in computer science education summit meeting, Orlando, FL.

Jonnasen, D. (2000). Toward a Design Theory of Problem Solving. *Educational Technology Design and Development, 48*(4), 63–85.

Jonassen, D. H., & Hung, W. (2008). All Problems Are Not Equal: Implications for Problem-Based Learning. *Interdisciplinary Journal of Problem-Based Learning, 2*, 6-28. https://doi.org/10.7771/1541-5015.1080

Justi, R.S. & Gilbert J. K., (2002). Models and modelling in chemical education, In J. Gilbert, O. De Jong, R. Justi, D. F. Treagust and J. H. van Driel (Eds.), *Chemical education: towards research-based practice* (pp. 213 - 234), Dordrecht: Kluwer Academic Publishers.

Kalovrektis, K., Lykas, Ch., Fountas, I., Gkotsinas, A., & Lekakis, I. (2013). Development and application embedded systems and wireless network of sensors to control of hydroponic greenhouses. *International Journal of Agriculture and Forestry, 3*(5), 198-202.

Kozma, R. B. (Ed.) (2003). *Technology, innovation, and educational change: A global perspective*. Eugene, OR: International Society for Technology in Education.

National Academy of Engineering (NAE) & National Research Council (NRC). (2014*). STEM integration in K-12 education: status, prospects, and an agenda for research*. The National Academies Press, Washington

National Academy of Engineering and National Research Council [NAE & NRC]. (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. Washington: National Academies Press.

National Research Council. (2012). *Discipline-based education research: understanding and improving learning in undergraduate science and engineering*. National Academies Press, Washington, DC.

National Science Teachers Association (2014). *NSTA position statement: Early childhood science education*. Retrieved from http://www.nsta.org/about/positions/earlychildhood.aspx

Nersessian, N. (1992). How do scientists think? Capturing the dynamics of conceptual change in science. In R. Giere (Ed.), *Cognitive models of science* (pp. 3-44). Minneapolis: University of Minnesota Press.

Ortiz, A.M. (2008). *Engineering design as a contextual learning and teaching framework: How elementary students learn math and technological literacy*. Paper presented at the PATT – 19, Salt Lake City UT.

Piaget, J. (1970). *Genetic epistemology*. New York: Columbia University Press.

Psycharis, S. (2016). The impact of computational experiment and formative assessment in inquiry based teaching and learning approach in STEM education. *Journal of Science Education and Technology, 25*(2), 316-326. https://doi.org/10.1007/s10956-015-9595-z

Psycharis, S. (2018). STEAM in Education: A Literature review on the role of Computational Thinking, Engineering Epistemology and Computational Science. Computational STEAM Pedagogy (CSP). *Scientific Culture, 4*(2), 51-72. https://doi.org/10.5281/zenodo.1214565

Roberts, C. (2012). *Information structure in discourse: Towards an integrated formal theory of pragmatics*. The Ohio State University.

Sarama, J., & Clements, D. H. (2009). *Early Childhood Mathematics Education Research: Learning trajectories for young children*. New York: Routledge

Savin-Baden, M. (200). *Problem-based Learning in Higher Education: Untold Stories*. Buckingham: The Society for Research into Higher Education/Open University Press.

Schultz-Ross, R. A., & Kline, A. E. (1999).*Using problem-based learning to teach forensic psychiatry*. Academic Psychiatry, 23, 37-41.

Schunn, C. (2011). *Design principles for high school engineering design challenges: Experiences from high school science classrooms*. Retrieved from. http://ncete.org/flash/pdfs/Design_Principles_Schunn.pdf

Sengupta, P., Kinnebrew, J. S., Basu, S., Biswas, G., & Clark, D. (2013). Integrating computational thinking with K-12 science education using agent-based computation: A theoretical framework. *Education and Information Technologies, 18*(2), 351-380.

Sentance, S., & Csizmadia, A. (2015).*Teachers' perspectives on successful strategies for teaching Computing in school*. Paper presented at IFIP TCS, 2015. http://community.computingatschool.org.uk/files/6769/original.pdf

Shirey, K. (2017). Teacher Productive Resources for Engineering Design Integration in High School Physics Instruction (Fundamental). In Proceedings of the 2017 ASEE Annual Conference, Columbus, OH, June 2017.

Skinner, B. F. (1954/1968). *The science of learning and the art of teaching. In B. F. Skinner (Ed.),* The technology of teaching (pp. 9–28). New York: Appleton Century-Crofts. (Original work published in 1954 in the Harvard Educational Review, 24(2), 86–97).

Springer, L., Stanne, M. E. & Donovan, S. S. (1999). Effects of Small-Group Learning on Undergraduates in Science, Mathematics, Engineering and Technology: A Meta-Analysis. *Review of Educational Research, 69*(1), 21–51.

Wicklein, R. C., & Schell, J. W. (1995). Case studies of multidisciplinary approaches to integrating mathematics, science and technology education. *Journal of Technology Education, 6*(2), 59-76

Weintrop, D., Beheshti, E., Horn, M. et al. (2016). Defining Computational Thinking for Mathematics and Science Classrooms. *Journal of Science Education and Technology, 25*(1), 127-147. https://doi.org/10.1007/s10956-015-9581-5

White, B., Frederiksen, J., & Spoehr, K. (1993). Conceptual models for understanding the behavior of electrical circuits. In M. Caillot (Ed.), *Learning electricity and electronics with advanced educational technology* (pp. 77-95). New York: Springer-Verlag.

Xenakis, A., Kalovreketis, K., Papastergiou, G. (2019). STEM Contribution of Educational Robotics Scripts to Physics and Mathematics to Enhance Computational Thinking. *Journal of Education and Sciences*, University of Thessaly.

Yadav, A., Zhou, N., Mayfield, C., Hambrusch, S. & Korb, J. T. (2011). *Introducing computational thinking in education courses*. In: Proceedings of the 42nd ACM technical symposium on Computer science education, ACM, pp. 465–470.

Yaşar, O. (2013). Teaching Science through Computation. *International Journal of Science, Technology and Society, 1*(1), 9-18. https://doi.org/10.11648/j.ijsts.20130101.12