The Impact of a Sustainable Progressive STEAM Program on Primary School Students' Critical Thinking Dispositions and Mathematics Achievements

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ABSTRACT

This study, which was supported by a quantitative research paradigm with two experiments and two control groups of 4 × 4 quasi-experimental design, aimed to find out the impact of a sustainable progressive STEAM (SP-STEAM model) application model on 5th-grade primary school students' critical thinking dispositions and mathematics achievements in North Cyprus. The treatment model was applied to two independent experimental groups for 14 weeks (first semester of 2021-2022 academic year). The split-plot multiple group analysis of variance (split-plot ANOVA) statistical techniques was used to calculate between- and within-group significances regarding exogenous variables. The SPSS-24 software package was used for the analysis. The Pre-test and post-test results deriving from the experiment and control groups revealed a significant effect of the SP-STEAM model upon the 5th-grade primary school students' critical thinking dispositions, as measured using the CCTDI, mathematic achievements, as well as measured using a dedicated exam. The results of the analysis showed that the experiment groups where the *SP-STEAM* program was applied performed better across all sub-dimensions of the CCTDI, in comparison to the control groups where the progressive STEAM program was not applied. Cross-sectional split-plot ANOVA results yielded that the experiment group 1 and experiment group 2 displayed statistically significant differences F(3100) 40.581, $p < 0.001$ in comparison to control group 1 and control group 2, across pre-post test results, in terms of mathematics achievement. No significant difference was observed in favor of control groups. The results were discussed in detail in light of the related literature, with suggestions for further studies proposed.

Keywords: STEAM Education, CCTDI, 5th-grade Primary School Students, Critical Thinking Dispositions, Mathematics Achievements.

ÖZ

Bu çalışma, 4×4 yarı deneysel tasarıma sahip iki deneme ve iki kontrol grubu ile gerçekleşmiş nicel araştırma paradigması tarafından desteklenmiştir. Kuzey Kıbrıs'taki ilkokul 5. Sınıf öğrencilerinin eleştirel düşünme eğilimleri ve matematik başarıları üzerinde sürdürülebilir bir ilerleyici STEAM (SP-STEAM modeli) uygulama modelinin etkisini belirlemeyi amaçlamıştır. Bu model, 14 hafta boyunca (2021-2022 Eğitim Yılı 1. Dönem) iki bağımsız deneme grubuna uygulanmıştır. Dışsal değişkenlere ilişkin olarak gruplar arası ve grup içi anlamlılıkları hesaplamak için split-plot çoklu grup varyans analizi (split-plot ANOVA) gibi istatistiksel teknikler kullanılmıştır. Analiz için SPSS-24 yazılım uygulaması kullanılmıştır. Deney ve kontrol gruplarından elde edilen ön test ve son test sonuçları, SP-STEAM modelinin 5. sınıf ilkokul öğrencilerinin eleştirel düşünme eğilimleri ve CCTDI kullanılarak özel bir sınav aracılığıyla ölçülen matematik başarıları üzerinde anlamlı bir etkisi olduğunu ortaya koymuştur. Analiz sonuçları, SP-STEAM programının uygulandığı deneme gruplarının, uygulanmayan kontrol gruplarına kıyasla CCTDI' nın tüm alt boyutlarında daha iyi performans gösterdiğini kanıtlamıştır. Kesitsel split-plot ANOVA sonuçları, deneme grubu 1 ve deneme grubu 2'nin matematik başarısı açısından ön-test ve son-test sonuçlarına göre kontrol grubu 1 ve kontrol grubu 2'ye karşı istatistiksel olarak önemli farklılıklar gösterdiğini (F (3100) 40.581, p< 0.001) ortaya koymuştur. Kontrol gruplarında anlamlı bir fark gözlemlenmemiştir. Sonuçlar, ilgili literatür ışığında detaylı bir şekilde tartışılmış ve ileriye dönük çalışmalar için öneriler sunulmuştur.

Anahtar Kelimeler: STEAM Eğitimi, CCTDI, 5. Sınıf İlkokul Öğrencileri, Eleştirel Düşünme Eğilimleri, Matematik Başarıları.

DEDICATION

This thesis is dedicated to my parents for their endless love, support and encouragement during my academic life. I hope this achievement would be an inspiration for success of my children.

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LIST OF SYMBOLS AND ABBREVIATIONS

CCTDI	California Critical Thinking Dispositions Inventory
Cs	Collaboration, Communication, Creativity, Critical Thinking
CTDs	Critical Thinking Dispositions
5E	Engage, Exploration, Explain, Eloboration, Evaluation Phase
NC	North Cyprus
PBL	Projet Based Learning
STEM	Science, Technology, Engineering, Mathematics
STEAM	Science, Technology, Engineering, Arts, Mathematics
SP-STEAM	Sustainable Progressive STEAM
TRNC	Turkish Republic of Northern Cyprus

Chapter 1

INTRODUCTION

1.1 Presentation

The backbone of any developed country and foundation of settled wellbeing of any nation have been based on a decent educational system which is supported and surrounded by pragmatical philosophy tracing back to the notions of John Dewey. However, the evolution of human being and technology had enormous amount of impact on our understandings and the way we interpret the universe around and within us. After a noticeably short time that Einstein declared matter is equal to energy ($E=MC^2$), doors of a new era, an era of quantum physics, have been opened with so many intriguing questions and developments along with it. Majority of scientists were aware that human race was pregnant to a dramatically new jump in civilization, and that was true. Quantum physics lead us to discover nano-transistors. For the one who never heart of it, nano-transistors are the core elements which established a set for the development of today's smartphones, touch screens, fibre-optic cables, and today's 10^{th} generation computer CPUs'. The question is, do we owe these technological advancements we experience today to the quantum physics which is successful in explaining the physical laws in the world of electrons. Or do we owe these advancements to some people who think in a totally different way than others. How did we bring such a change into being?

We know that there are tons of unanswered questions that need to be answered for the shake of science and development. 21st century, as was accepted by many scientists and scholars, are neither alike previous ones nor will look like the next ones. Unpacking this statement gives us clues about the dramatically expected changes that human being will experience in the future. Although this sounds frightening, one should not take it for granted, says Shankar (2010). Shankar, however; adds that what is frightening is which societies will manage to cope with these changes and survive in the new world order and understanding of the universe. A drastically forcing question bringing us to a certain place where we begin to have problems. The problem is causally related to the readiness of countries and societies for the future. But how can a society be ready to become a part of this geometrically expanding changes in the field of technology and science? Majority of scholars and pioneers of the field answered this question by a decent education which is designed by the STEM (Science Technology Engineering Math) approaches.

The consideration of this context has led countries to change their education policies and in parallel to this need, developments in all fields have accelerated in the 21st century. Nowadays, professionals who specialize in science, technology, engineering, arts and mathematics (STEAM) fields have been as one of the most important factors for a country's innovation and economic development (Carnevale et al., 2011; PwC Turkey and TUSIAD, 2017). The individuals who can keep pace with the progresses and changes of today's digital era, which is extraordinarily rich in terms of information and technology, are expected to be STEAM employees who possess the 21st century skills. These skills are namely innovation, creativity, communication, problem solving, and critical thinking (NCREL and Metiri Group, 2003; P21, 2016; World Economic Forum, 2015).

The need to develop individuals who are keen to ask new questions and create practical solutions to the problems have become the most recent problem of educators and researchers that they seek answer for. STEAM education on the other has been considered as one of the most important answers to this intriguing question. It is inevitable for any society to adapt and revise their educational systems to STEAM education to cope with the challenges we face today. For that matter experimental studies exploring the effects of various implementations of STEAM education to different cultural groups and societies have accelerated in number in the last decade. The common share point of these studies were to find out the most suitable form of application of STEAM principles to their ongoing natural order and find an intellectual home where they can produce the desired outcomes for their youth and nations. As these studies increase in number, many societies have recently begun to make new implementations to find the best way to achieve their goals.

1.2 Statement of the Problem

Over the last years, the demand for improving critical thinking dispositions (CTDs) of primary school students led educators, researchers, and program developers consider issues related to developing and adapting effective intervention strategies high on their agenda (Afdareza, Yuanita, & Maimunah, 2020; Gulhan, & Sahin, 2016; Nurwahyunani, 2021; Sullivan, 2006). The basic premise behind this movement is related to the notion that the earlier students were encountered with opportunities to gain critical thinking dispositions the more effective and successful will they be in critical thinking and academic achievement in their further careers (Afdareza, Yuanita,

& Maimunah, 2020; English, and King, 2018). For this reason, studies have accumulated to propose different strategies to nurture or enhance CTD of students at different levels of education. The most intriguing strategy to foster CTD of primary school students was proposed to be the application of STEM (Science Technology Engineering Mathematics) oriented educational programs (Gillies, 2018; Gomez and Albrecht, 2014; Priatna, Lorenzia, & Widodo, 2020). STEAM oriented educational programs are considered as inevitable parts for helping primary school students gain critical thinking dispositions and improve their skills in science, technology, engineering, arts and mathematics (Zeid, Chin, Duggan, and Kamarthi, 2014).

Nonetheless, a paradigm shift in education requires important educational policies, and numerous countries have tried different strategies to adapt their educational settings to STEAM education as a new paradigm. A very recent and comprehensive book titled 'Status and Trends of STEM Education in Highly Competitive Countries: Country Reports and International Comparison' summarizes the issues and solutions that several countries have experienced and tested (Lee & Lee, 2022). As Lee and Lee summarize, the common issues among many countries such as Canada, Finland, Germany, Hong Kong, Ireland, Singapore, Sweden and Taiwan, were teacher training, materials, and methods of STEAM education. For that reason, the paradigm shift began with teacher education and training and continued with material development and methodology of teaching in those countries (Lee & Lee, 2022). Teachers have been considered as the most crucial part of STEAM education. A very recent study which systematically reviewed experimental studies regarding STEAM applications worldwide reported that 95% of experiments have first concentrated on training teachers prior to any treatment application and summarized that any application without training of teachers would not be effective (Hebebci, 2023). While studies report that experimental studies regarding STEAM education will mostly fail without in-service teacher training, the question arises as to why teachers are found to be inadequate in application of STEAM in classrooms. The answer to this question is based on the pre-service teacher education curriculum within the scope of many studies (Parlakay & Koç, 2020; Arshad, 2021). In STEAM applications, the question is actually how it is taught rather than what is taught. A study carried out in Turkey suggested changing the policy and curriculum in Teacher Education Programs within Education Faculties throughout Turkey because graduate teachers see students as passive receivers of information rather than active interpreters of knowledge and experience (Duban & Aydogdu, 2018). Therefore, STEAM and its applications for the betterment of education and for expected transitions in societies should be understood well in order to know where to start the paradigm shift.

STEAM, by many researchers, is defined as an educational approach that aims to provide students with interdisciplinary cooperation, openness to communication, ethical values, research, production, and problem-solving skills using creativity by focusing on the engineering design of knowledge and skills in the fields of science-technology-engineering and mathematics (Buyruk and Korkmaz, 2016; Karakaya et al., 2018; White, 2014). There are many different studies that reveal the strong link between STEAM education, critical thinking, and mathematic achievement, yet most of them are theoretical and need to be empirically tested (White, 2014). Lately, some studies conducted on the phenomenon of critical thinking and STEAM education display some empirical support for the strong tie between the application of STEM education and improvement in CTDs and mathematic skills (Carroll, 2014; Gulhan &

Sahin, 2016; Hacıoğlu & Gülhan, 2021). These studies, however, carried out correlational effects, which are valuable in supporting the proposed theory, yet are insufficient in supporting the true causal differences that STEAM education programs possibly made on students' CTD and their academic achievements. With respect to the specified lack of related literature on the possible casual comparative effects of STEAM applications on primary school students' CTDs and academic achievements, the current research aimed to test the impacts of a sustainable progressive STEAM model on primary school students' CTDs and their mathematics achievements. North Cyprus (NC) is one of those countries that is ripe for an upcoming drastic change in its educational system. Although it is known that STEAM education has some rigid principles in application, it also does maintain some flexibility to be embedded in an existing educational system (Gomez & Albrecht,2014). In addition to the need for STEAM education, researchers question the way it is administered and practiced (Gomez & Albrecht, 2014; White, 2014). This is crucial because every society has its own dynamics and cultural realms. The extraneous factors that might possibly affect the process of administration of this approach are unknown, and there are no experimental results supporting the success of such an administration. This is quite important, because not every practice gives the same results and not every culture holds and responds to a new design the same way. For that very reason, it has long been an urgent need to design a STEAM education approach to be embedded in the educational context of NC and to elicit empirical evidence regarding its effects on the targeted audiences' academic achievements and thinking qualities.

For educators, there is now a greater need for science, technology, engineering and maths (STEM) concepts to integrate with the arts (STEAM) across the wider curriculum. We know this because business and industry broadcast that future-ready employees need to have multiple areas of expertise or at least appreciate how a range of skills fit together. Teachers working in cross-curricular STEAM settings often see their students making connections between concepts and solving problems in new and exciting ways. They demonstrate this by active engagement, their discoveries visible in enthusiastic moments.

STEM represents science, technology, engineering and maths. “STEAM” represents STEM plus the arts – humanities, language arts, dance, drama, music, visual arts, design and new media. The main difference between STEM and STEAM is STEM explicitly focuses on scientific concepts. STEAM investigates the same concepts, but does this through inquiry and problem-based learning methods used in the creative process. This looks like groups of learners working collaboratively to create a visually appealing product or object that is based in the understanding of a STEM concept, such as the mathematics of the parabola used to create fine art imagery.

STEAM is not a new concept. People such as Leonardo Da Vinci have shown us the importance of combining science and art to make discoveries.

1.3 Purpose of the Study

The vision of NC education for 2030 strategic aims, which were determined by the Ministry of National Education, underlines the importance of appropriate application models of STEAM education (National Report of Ministry of National Education, 2019).

If a nation desires to have an international position in fields such as scientific, economic, or technology, STEAM education must be considered in its education systems (Yasin, et al., 2020). However, in-depth research carried out found that studies on STEAM applications for primary school students are quite limited in NC. Therefore, the STEAM application within the classroom at the primary school level was deemed necessary. One of the results of the Vision 2030 Education Strategic Plan Workshop Report, as announced by the Ministry of National Education of North Cyprus, was the call for studies on various adaptable applications of STEAM education models.

Consideration of the context provided in the problem statement section of this chapter leads to concentrate on development, application and assessment of a progressive STEAM education model to administer in primary schools to have positive effects on targeted audiences' academic achievements and critical thinking dispositions. The purposes of this research, therefore, are to investigate the impact of a sustainable progressive STEAM education model on the critical thinking dispositions and academic achievements of 5th grade primary school students in public schools in the TRNC.

1.4 Research Questions

Based on a developed framework, the current research, which is supported by a quantitative empirical paradigm, aims to figure out the possible effects of a sustainable progressive STEAM education model on groups of 5th-grade primary school students' CTDs and their academic achievements in NC, asking the following research questions:

1. Will groups of 5th-grade primary school students who are instructed by a SP-STEAM education model, show statistically significant differences in comparison to similar groups of 5th-grade primary school students who are

instructed with a traditional education model in terms of their critical thinking dispositions?

2. Will groups of 5th-grade primary school students who are instructed by a SP-STEAM education model show statistically significant differences in comparison to similar groups of 5th-grade primary school students, who are instructed by a traditional education model in terms of their mathematics achievements?

1.5 Importance of the Study

The study is important from several perspectives. First, the current study is the first of its kind that tends to design a STEAM education model specific for TRNC culture and educational expectations. Second, the results of this quasi-experimental study will bring us deeper insights into how to tackle with the challenges of the 21st century. Third, we will learn more about the most suitable form of STEAM education model as we progress in this study. Moreover, the results of this study would provide many benefits for the primary school teachers in utilizing effective teaching methods to help students acquire critical thinking skills. Findings are also expected to increase both learning environment and students' learning motivation in primary schools in Northern Cyprus. As a result, learning efficiencies will be increased. In addition to all, the results will provide important contribution for the educational development in the primary schools of North Cyprus in facilitating the development of critical thinking dispositions. STEAM practices could be planned to become widespread in Northern Cyprus education system in the light of the findings to be obtained at the end of this research.

1.6 Assumptions and Limitations

1.6.1 Assumptions

a. It is assumed that the only difference between the experiment and the control group would be due to the teaching model, while the other variables that cannot be taken under control affect the groups equally,

b. It is assumed that the experts consulted during the preparation of data collection tools, review of the activities and analysis of the data would be sincere in their opinions,

c. It is assumed that students respond realistic and sincerely to the data collection tools used in the research,

d. In group studies with teachers, the answers given by teachers are assumed to be the teacher's own opinion,

e. It is assumed that the researcher is not affected by prejudices during the research,

f. It is assumed that the content of the STEAM curriculum and teacher-student handbook prepared by the researcher has been checked for compliance with the curriculum by the STEAM education experts,

g. It is assumed that teachers received volunteer 2 weeks, total 16 hours STEAM education,

h. It is assumed that STEAM teacher in-service program will be designed as project-based

interdisciplinary integration approach.

i. It is assumed that the social activity is defined as cultural, musical, art, theater, cinema or sportive activities.

j. It is assumed that the technological usage is defined as social media, watching TV, PlayStation, reading on electronic screen, and all electronic tools.

k. It is assumed that mathematics exam scores are defined standard math’s exam before and end of the semester.

1.6.2 Limitations

a. Findings will be obtained only in the first semester of the 2021-2022 Academic year because the study will be carried out in the compulsory mathematics and science courses,

b. Only the 5th grade students of primary school who are enrolled in the all lesson will be the chosen as the participants of the study,

c. The quantitative sample group of the study will be 104 students,

d. The study will only be limited to academic activities carried out for 14 weeks.

Chapter 2

REVIEW OF RELATED LITERATURE

2.1 21st Century and STEAM Education with Its Counterparts

Today's societies are characterized by constant changes and competition, educators and employers are seeking students who are equipped with critical thinking skills to face challenges, to make the right decisions, to build an integrated personality capable of participating in a society, to share different point of views, and ultimately to solve national problems (Bae, Yun, & Kim, 2013). Developed countries are continuously renewing their education programs to educate qualified individuals (Bybee, 2010; Sanders, 2009). As a result of developing 21st century literacy skills, students will make more informed decisions. As a result, they will positively affect the social and economic development of their country (Figliano, 2007).

STEAM education has an especially important position in terms of literacy developments in today's education (Kuenzi, 2008). It was first sung by Judith Ramaley in 2001 and appeared in the USA (Teaching Institute for excellence in STEAM, 2010; Yıldırım and Altun, 2014; Zollman, 2011). Although it looks like an abbreviation of words, it is more comprehensive than an abbreviation. STEAM education, science, technology, engineering, arts and mathematics are given in an integrated manner. Educational approaches are associated with daily life and supported by 21st century skills (Yıldırım and Altun, 2014; Yıldırım, 2016). Today, STEAM education is practiced in different ways in many countries, and many studies are carried out on this subject (Banks and Barlex, 2014; MEB, 2016).

There are many important reasons why so much work has been done on education. STEAM education establishes industry-school connection. It allows interdisciplinary work; learned for the information to be included in everyday life, to give importance to vocational education and for the 21st century business world which contains necessary skills and equipment (American Institute of Physics [AIP], 2015; Banks and Barlex, 2014). STEAM education increased the academic success due to developing science, mathematics, and technology literacy in International PISA/TIMSS exams. STEAM education is important due to reasons such as technological progress (Dugger, 2010). STEAM education should be placed on a good philosophical basis, because successful results may not be achieved in a STEAM education whose philosophical foundations are not well established.

STEAM education is an educational approach in which different disciplines are given in an integrated way (Zollman, 2011). STEAM integration process traces back to the opinions of educators like John Dewey and Kilpatrick. When the opinions of these educators are examined, it is revealed that they are student-centered, connected with life and they argue that education should be interdisciplinary. It also forms the foundations of the progressive educational philosophy (Yıldırım, 2016). When viewed from this angle, it can be said that the fundamentals of STEAM education constitute a progressive education philosophy (Selvi and Yıldırım, 2016). The philosophy of education is to determine the goals of a given education, individual and social compliance, and the quality of educational practices. Although it plays an active role in its determination, it creates an integrated and consistent perspective on education

(Sözer, 2008). An educational program which is simply composed of aims, contents, materials and methods and evaluation were said to be formed by an educational philosophy behind. Likewise, it is the policy of education which determines the ingredients of all necessary inputs, processes, outputs, and evaluation of that system. Like any system of thought, STEAM has got its own principles that tend to shape the way individuals should think in line with a given education. The question, however, turns to be what kind of a profile individuals should hold when they are graduated from high schools and what benefits they would gain to the societies in which they live. Moving from that point of view on, teachers become the key players who will be applying the designed curriculum in the most appropriate way. In this sense, teachers have a great deal and effect on the targeted audiences. Enough experience, knowledge, pedagogical experience, and content expertise are necessary to fulfill the expected capacity from teachers to cope with the challenges in teaching learning situations (Shulman, 1987). This is truly valid for teachers who should be able to provide STEAM education. Education should be dominated by all dimensions. STEAM pedagogical domain should know his/her knowledge well. Teachers who are not familiar with the pedagogical aspects of STEAM are not capable of applying its principles effectively, therefore teachers may need to be trained prior to any attempt in administering STEAM principles in classes (Yıldırım, 2016). In this regard, effective STEAM education requires a progressive perspective with a decent plan of implementation that is supported by a strong theoretical framework.

As Margot and Kettler (2019) examined teachers' perceptions of STEAM integration and education in curriculum for K-12 schools, teachers’ beliefs and their perceptions regarding STEAM play crucial role because their beliefs are determinant factors in terms of their success in implementing STEAM procedures in their instructions. Some studies about teachers' perceptions of STEAM education reported barriers including pedagogical challenges, curriculum challenges, structural challenges, and concerns about students, concerns about assessments, and lack of teacher support. Teachers inevitably required supports that would improve their effort to implement STEAM education denoted with collaboration with peers, quality curriculum, district and school support, prior experiences, and effective professional development. Marget and Ketler (2019) recommended quality STEAM in-service training, cooperation with the business community and support STEAM education practices by school administration and families.

Gomez and Albrecht (2013) say that pedagogical aspect of STEAM education is important in terms of resolving problems that might occur during instructions. Such methodology helps individuals integrate in-class learning to real life experiences to further guide their full careers in time.

The philosophy behind engineering is so crucial in a sense that they are expected to solve problems. Problems that are integrated in life and that exist in life. Solving problems is the key element of engineering. Students learn as they experience scientific methodology, experiment, and precautions of engineering together with mathematics (Mooney and Laubach, 2002). However, for students to experience the instruction in such ways, teachers need to be very skillful and creative to create them the desired learn by doing experience through teaching learning processes.

Wang, Moore, and Roehring (2011) examined the teacher perceptions and practices of STEAM integration and noted key findings. These common findings were 1) How research defines the perceptions of teachers regarding their of STEAM educational models? - Teacher variables, application activities, cross-curricular integration, student enjoyment, student struggles, and value of STEAM are some of the thematic expressions caught by researchers with respect to the perceptions of teachers who tended to use STEAM education models or who tended to integrate STEAM model into existing teaching strategies.

2) What problems teachers experienced and reported as they use STEAM education models? Pedagogical, curricular, structural, student concerns, assessment, and supports were some of the themes emerged regarding to sort of problems they experienced in application of STEAM education.

3) What kind of supports teachers needed in implementing STEAM strategies into their instructions? Most of the teachers reported the need to have extra support of a second professionalized teacher in classrooms. This is because teachers felt deficiencies in creating collaboration in classroom environment. As they stated, creating a collaborative environment is so difficult in a STEAM oriented classroom education.

Moreover, it is stated that teachers should have a strong belief in the success of STEAM education to be successful in long run. Research also supported the notion that the more teachers apply STEAM the more successful their students get and the more the teachers motivated to use STEAM education. Moore et al. (2014) suggested that STEAM can be applied at schools of different cultures. However, schools which holds students of different culture and diverse ethnic backgrounds requires teachers who can cope with cross-cultural school environments and must be familiar with the sort of problems that might be experienced within the teaching learning processes. One of the concerns of teachers was that they had difficulties in applying STEAM education models in cross-culturally diverse classroom environments (Asghar et al. 2012; Dare et al. 2014). Understanding students' progress, their challenges, difficulties they experience, pros and cons for individual differenced in a cross-culturally diverse classroom environment was reported to be main problems that teachers experience in implementing STEAM education models (Tomlinson and Moon 2013). For this reason, more research studies, especially experimental ones, are suggested to be conducted for further investigation into the application procedures of STEAM in cross-culturally diverse school environments (Dare et al. 2014). In order for teachers to gain confidence in using STEAM education models, teachers need to be supported with workshops, seminars, and programmed in-service teacher training programs (Nadelson et al. 2012; Nadelson et al. 2013).

STEAM education has an important position among the developments in today's education system (Kuenzi, 2008). To succeed and become competent, students should possess the needed critical thinking skills and utilize them in their daily lives, which may allow them to organize and evaluate the information they receive from reading books and by attending school. Some researchers have reported a number of critical thinking skills that students should possess, such as being able to evaluate discussions, explain information, and test hypotheses (Hassan & Madhum, 2007), distinguish facts, determine right answers from wrong answers, determine right resources, solve problems and the ability to make predictions (Beyer, 1985). Moreover, critical thinking skills have been found to influence students' achievement and motivation in learning process (Bae, Yun & Kim, 2013).

In addition, the factors are mentioned on the students' academic success and motivation; some studies have indicated several factors which could contribute to the emergence of gender differences by Finn (1980), and Taiwo & Molobe (1994). The other factor is believed to be family influence and social-economic status of parents and culture and traditional influences that are related to students' social life (Wilcox, et al., 2005).

STEAM education is a newly developed paradigm that was embedded in 2011. The goal of STEAM education is to increase students' problem-solving skills and their interest in science and technology. Accordingly, the Korean, USA and UK Ministry of Science and Technology stated that STEAM education will help improve the nation's science and technology competition (Maes, 2010). Although art and design are often used in the same sense, there are some differences between the two concepts. These differences become more evident day by day. In STEAM understanding, there is a phenomenon of art based on design, which is indispensable in technology (Ayvacı & Ayaydın, 2018).

STEAM education emphasizes an interdisciplinary approach for the student's to better prepare for business life. Increasing the number of students with STEAM education and employing these students in industry are among the most important targets for the countries. To achieve this goal, there is a need for teachers who have sufficient and qualified STEAM in-service training because an effective implementation of a STEAM-based curriculum is only possible with qualified teachers (Wang, 2013). Also, it is important to prepare the teaching programs using a multi-disciplinary teaching method by integrating engineering and technology into science, art and mathematics subjects (Ramaley, 2007). Based on these findings and the presented theoretical framework, teachers should be trained and guided of the best way of utilizing effective teaching method into their classroom.

It is necessary to prepare learning environments and activities that will increase the thinking skills of the students from early ages and improve their knowledge level to solve the life problems they encounter (Akbıyık & Kalkan-Ay, 2014). It is important to prepare STEAM-focused activities both in developing experiences and increasing the permanence in learning. Because STEAM activities enable students to be active in the education process (Bransford, Brown, & Cocking, 2000). In addition, STEAM focused activities offer students the opportunity to find solutions to real life problems and to test the hypotheses they have developed (Sanders, 2009).

According to Ostler (2012) STEAM education emphasizes an interdisciplinary approach to better prepare students for STEAM disciplines. STEAM is much more than the naming of five integrated disciplines. The integration of these five disciplines is extremely important. Integrated STEAM education may have learning objectives based on one of the disciplines, but it also includes a link to other STEAM topics. It has been reported by STEAM professionals that STEAM education has the advantages of increasing students' level of success and providing them with exciting and motivation to better prepare students for business life and make topics more interesting (Heil, Pearson, & Burger, 2013). According to another approach, art should be included in STEAM education by changing the abbreviation STEAM to STEAM. The reason for this is the claim that engineering process education emphasized by STEAM requires a design and artistic or creative perspective. This approach has the potential to design thinking by adding art (art) to STEAM education to make art education and effective student engagement, creative process, and STEAM (Bequette & Bequette, 2012).

STEAM is a kind of teaching strategy which intends to help targeted studensts with interdisciplinary approach to create open-minded and communicative beings who can come up with unique solutions to suggested or defined problems. Because communication was said to be the core element of cooperation and collaboration (Buyruk and Korkmaz, 2016; Karakaya et al., 2018a). STEAM, which forms an integrated model with the combination of different disciplines, enables students to look at the problems they face in a wide perspective. STEAM also includes 21st century skills that education systems aim to gain in students (Baran, Canbazoğlu Bilici, Mesutoğlu and Ocak, 2016). For this reason, using the activities prepared within the scope of STEAM education approach will enable students to develop the skills of science-technology-mathematics-arts and engineering disciplines (MacFarlane, 2016) and increase their readiness (Thomasian, 2011). In order for countries to have a voice in the international arena, to compete and grow economically, STEAM approach should be included in the education system (Çorlu, Capraro & Capraro, 2014; Lacey & Wrigh, 2009). In Turkey this context, the Ministry of National Education, published by Science from 4th Course in Teaching Program "Science, Engineering and Entrepreneurship applications," says the subject field is added (Karakaya, Unal, Lawn and Yilmaz, 2018b). The subject of Science, Engineering and Entrepreneurship practices aims to help students establish the connection between engineering and science, understand interdisciplinary interaction and develop a world view by transferring what they learn to their lives (MEB, 2018).

When the related literature was examined, (Akbıyık and Kalkan-Ay, 2014; Altan and Üçoğlu, 2018; Eroğlu and Bektaş, 2016; Tekerek and Karakaya, 2018; Timur and İnançlı, 2018; Uğraş and Genç, 2018; Uğraş, 2017) It is seen that there are different studies in which the opinions of teachers and prospective teachers about STEAM education were determined (Geng, Jong and Chai, 2019; Siew, Amir and Chong, 2015; Wang, Moore, Roehrig and Park, 2011). For example, Eroğlu and Bektaş (2016) determined the views of STEAM-educated science teachers about STEAM-based course activities. In the research carried out by Uğraş and Genç (2019), pre-service teachers' opinions about STEAM education and their orientation towards integrated STEAM education were obtained. Yıldırım and Türk (2018) have determined the opinions of elementary teacher candidates about STEAM education. In their study, Geng, Jong and Chai (2019) found out the concerns and self-efficacy of teachers working in the International Journal of Educational Sciences in Hong Kong 4 about STEAM education. However, it has been determined that the studies (Baran et al., 2016; Özcan and Koca, 2019; Yıldırım and Selvi, 2018) in which the opinions of primary school students about STEAM education and activities were determined are not sufficient.

STEAM approach in teaching programs in Turkey have been reported in many studies that took place at the desired level (Akgündüz et al., 2015; Hacıoğlu, Yamaga and Poplar, 2016; Tekerek and Karakaya, 2018). The Republic of Turkey Ministry of National Education has initiated a study to pass and referred to the importance of STEAM education is primarily organized to give place to STEAM activities of science and mathematics curriculum. In addition, the importance of shaping the exam system in this direction and supporting the students' metacognitive skills was emphasized. In addition, the necessity of reorganizing science laboratories in accordance with STEAM education and preparing course materials for STEAM applications has emerged (MEB, 2018).

However, there is no study in the STEAM application of the Ministry of National Education of the Turkish Republic of Northern Cyprus. Some of the work done in Turkey are as follows: Hacıoğlu, et al. (2016), science-technology-engineering mathematics activities and their impact on middle school students; Korkmaz and Buyruk (2016), the validity and reliability study of the STEAM awareness scale; Gökbayrak and Karışan (2017) is the study of sixth grade students' views on STEAM-based activities. In addition, Ercan and Şahin (2015), the effect of design based science education on students' academic achievement; Yamak, Bulut and Dündar (2014), the effects of STEAM activities on 5th grade students' scientific process skills and their attitudes towards science; Bozkurt (2014), the effect of engineering design science teachers on their decision making skills, scientific process skills and perceptions about the process.

Increasing the number of students who have received STEAM education and employing these students in industry are among the important targets for countries. Sufficient and qualified teachers with STEAM training are needed to achieve this goal. Effective implementation of a STEAM based curriculum is only possible with qualified teachers (Wang, 2012). It is important to prepare curriculum using a multi-disciplinary teaching strategy by integrating engineering and technology into science and mathematics subjects (Ramaley, 2007). With the addition of the dimension of art to this understanding, it is also of great importance to raise aesthetic anxiety in children from a young age and thus raise individuals who are prone to art and art lovers.

In recent years, the importance of providing students with a strong education in Science, Technology, Engineering, Art and Mathematics (STEAM) has been stressed. Qualified STEAM professionals are needed to remain economically competitive in the global market and to fill contemporary demands such as ensuring sufficient and sustainable energy, efficient healthcare and well-considered technology development (Bae et al., 2011).

STEAM education, which includes interdisciplinary approaches to science, technology, engineering,art and mathematics, has gained worldwide significance with its innovative approach to education (Gonzalez & Kuenzi, 2012). “The notion of STEAM education is aroused based on the need of raising citizens who can contribute to nations’ economic and cultural competency, in the new information era that we are living.” (Soylu, 2016, p.38).

Bybee (2013) claims that the four themes that set the STEAM reform apart are citizens' awareness of global challenges, shifting attitudes toward environmental issues, acknowledging the skills needed for the workforce of the twenty-first century, and persistent concerns about national security. We can define STEAM education as an interdisciplinary strategy that supports national growth as well as the development of high-level thinking skills and workforce readiness for the twenty-first century. These definitions and explanations align with each other.

Today, individuals are expected to have interactive skills such as taking their own learning responsibilities, thinking, questioning, transforming what they have learned into skills and adapting them to daily life situations, analyzing events, establishing original connections, interpreting the results in the light of scientific data, collaborating, and using the opportunities of technology appropriately and effectively. Skills that include creativity and intellectual curiosity, critical thinking, information and media literacy, collaboration, problem identification, resolution, self-direction, entrepreneurship, flexibility, intercultural interaction, social responsibility dimensions are defined by educational scientists as 21st century skills (Ananiadou, Claro, 2009; Rotherham, Willingham, 2010). In the 21st century, importance is attached to the development of skills such as critical thinking, problem solving, entrepreneurship, productivity, innovation, leadership, responsibility, knowledge, media and technology literacy (Partnership for 21st Century Skills, 2009).

The 21st century workforce skills are also compatible with scientific research and engineering design (Bybee, 2010a) and have a great importance in professional success (Akyıldız, 2014). In today's world, the need for people who can think and produce in fields such as science, technology, engineering, arts and mathematics, and who have the ability to question and creativity is growing. For this reason, it is necessary to innovate and differ in the programs applied for teaching-learning processes in these fields. The best examples of these applications are STEAM trainings and practices. In this century, many professions require STEAM knowledge (Lacey & Wright, 2009) and STEAM education has an important role in preparing students for the 21st century workforce (Sahin & Top, 2015). In addition, STEAM education plays a fundamental role in the economic, technological and scientific development of countries (Means, Wang, Young, Peters & Lynch, 2016; Sahin, 2013; Sahin & Top, 2015). Therefore, this situation necessitates the implementation of STEAM education in learning environments to acquire the knowledge and skills required by the 21st century. Furthermore, according to the National Society of Professional Engineers (2013), all people, including those who are not in the STEM fields, should possess the knowledge and abilities needed to meet the demands of our highly technological and information-based society. All students should prioritize their education in order to develop STEAM literacy, which is defined as understanding the nature of science, technology, engineering, arts, and mathematics as well as being familiar with some of the basic concepts from each discipline (Bybee, 2010; National Academy of Engineering and National Research Council, 2014).

Overview of the instructional practices from research papers; STEAM education is an interdisciplinary approach to learning that removes traditional barriers separating the five disciplines of science, technology, engineering, arts and mathematics and integrates them into real-world, rigorous, and relevant learning experiences for students.

2.2 Critical Thinking as an Inevitable Component of STEAM Education

Critical thinking is a learning strategy that aids the learner to process and integrate information more deeply. The National Council for Excellence in Critical Thinking, Scriven and Paul (1987) defined critical thinking as "The ability to think critically". It involves some skills: flexibility, originality, fluency, elaboration, brainstorming and modification. It is important, because it enables one to analyze, evaluate, and explain the structure of our thinking.

Fisher (2007), Karahoca, Karahoca and Yengin (2010) defined critical thinking as the ability to interpret and evaluate observations effectively, to communicate and to discuss. Accordingly, for an individual to have a critical thinking ability, they primarily have to be open to innovation and change. Similar to this definition, Jitgarun and Tongsakul (2009) indicated that individuals who are critical thinkers can accept or reject an explanation, event or situation through evaluation. While Facione (2007) stated that critical thinking is a thinking process that has both cognitive and philosophical bases; according to Delaney (2007), critical thinking is a process that is composed of recognition skills of collective perspectives by thinking in a reflective, rational, interrogative way in order to better understand the world. Critical thinking is still considered to be a heterogeneous concept and many ideas are being proposed related to the process (Nieto and Saiz, 2008; Saiz and Rivas, 2008). Critical thinking is a process that includes searching for information through reasoning skills, problem solving and decision making, and it allows people to obtain more effective results (Saiz and Rivas, 2011).

Hürsen and Kaplan (2012) described critical thinking as an active and organized mental process that allows us to understand ourselves and events occurring in our environment by being aware of own thinking processes, considering other individuals' thinking processes and applying our learned information.

When we look at successful countries in the field of education according to international test scores as Singapore, Austria, USD, Finland, it is clear that students give importance to free and independent thinking as well as research and inquiry. The Ministry of Education of the Republic of Turkey since 2003 and the Turkish Republic of Northern Cyprus Ministry of Education since 2005 were directed to make drastic revisions in the curriculum. In all lessons for each age group, the curriculum revision process started on the basis of the constructivist teaching approach. While teaching processes, teaching methods and curricula are being revised, it is stated that eight basic skills should be gained. These skills are listed as critical thinking, creative, problem solving, research-inquiry, communication, enterprise skills, using information technologies and using Turkish correctly, effectively and beautifully (MEB, 2005; 2007).

In the face of various amount of information presented for the use of students today, the student provides the right information by questioning the information s/he has received with critical thinking skills. When critical thinking is not used, different thoughts cannot be expected to develop (Göbel, 2013). Therefore, the ability of critical thinking has an important effect in questioning the information obtained by people and being able to efficiently participate in the society as an individual.

2.3 Goals and Guiding Principles of STEAM Education

STEAM is focus on two main goals in global practices. In the light of the findings obtained from STEAM education practices, common achievements will contribute to both individual and national development. These goals and achievements are: i) Improving functional and harmony in our highly technological world. Common achievements are personal decision making, participation in civil and cultural affairs, economic productivity. ii) Connecting between disciplines to better understand real life problems. Common achievements are deepened conceptual understandings, skills and concepts all work together and interconnected all disciplines (Vasquez, 2016).The objectives of STEAM education can be expressed as follows;

Science Literacy: It refers to the ability to use scientific knowledge and process to understand the natural world, as well as the ability to participate in discussions concerning the natural world. Technology Literacy: It means that students should know how to use new technologies, understand how new technologies are developed and gain the ability to analyze how new technologies affect the world.

Engineering Literacy: It refers to understanding how technologies are developed through the engineering design process, using project-based courses with an integrated and interdisciplinary approach style.

Art Literacy: Creativity is a great motivator during a child's education. Giving children the ability to create something of their own from an initial idea allows them to engage a number of skills they build on throughout their education. The following skills highlight why students need art literacy, creativity and hands-on experience all working together; Conceptualize an idea,Interpret meaning from their work, present their work to a parent or group, relate their art to broader concepts, expand on their art through storytelling, analyze the work of others Tied to this creativity will be a grounding in art literacy, which will involve the ability to communicate an idea both visually and verbally, and the knowledge to contextualize their idea within the wider art world.

Mathematics Literacy: Expresses the skills of analysis, reasoning and expressing ideas effectively by exposing, formulating, solving and interpreting mathematical problems (Armknecht, 2015; Thomasian, 2011).

STEAM guiding principles are: i) Focus on integration, i.e. connect concepts that seem disjointed, ii) Establish relevance, i.e. real-world problem, current event, global issue, iii) Emphasize 21st Century skills, i.e. access information, creatively solve problems, teamwork and collaboration, iv) Challenge you students, i.e. not so difficult that students give up, nor so easy that students find the work boring, v) Mix it up, i.e. project based teaching approach (Jolly, 2016). Guiding principles are important for obtaining efficiency in the preparation and implementation of STEM education.

2.4 Historical Aspects of STEAM Education

Behaviorism, cognitivism, and social constructivism are the three most important school of thoughts that have impact on education (Ertmer and Newby, 2013; Greeno et al., 1996). Behaviorism which established a basis for the birth of other school of thoughts has dominated education for years (Dilshad, 2017; Stavredes, 2011). In accordance with behaviorism, knowledge is considered as a result of behavior and behavior is coded as a sole result of learning process. (Greeno et al., 1996; Stavredes, 2011). Hence, learning is understood to be a result of stimulus-response-reinforcement where reinforcement can be either positive or negative (Stavredes, 2011). In contrast, cognitivism concentrates on mind and generates a greater understanding into learning by means of cognitive process that takes place in the brain of an individual, specifically the way human organizes information and the way codes them in a unique way (Ertmer and Newby, 2013). Following the principles of behaviorism, knowledge is a result of human behavior whereas, cognitivism focusses on comprehension, interpretation, organization and processing knowledge through human memory rather than passive acquisition of knowledge as a form of behavior (Stavredes, 2011). Thus, learning is understood to be a result of a more complex process going on in a brain of individual with a specific focus on how knowledge has been generated and organized under different circumstances (Ertmer and Newby, 2013). Behaviorism and cognitivism both agrees upon an idea that learning is a unique process for individuals since life experiences through behavior or cognition are quite unique for individuals (Ertmer and Newby, 2013). In contrast, social constructivism puts forward that leaning is more of a social issue within which individuals are connecting and interacting with one another to construct meaning and information (McKinley, 2015). In line with social constructivism, students build information through social interactions (Ertmer and Newby, 2013; Stavredes, 2011). Thus, following the principles of cognitivism, learner is accepted to be the sole person who directly contributes to the process of self-learning through social interaction (Ertmer and Newby, 2013).

Many studies have been produced in accordance with those school of thought in the context of STEAM (Science, Technology, Engineering, Arts, and Mathematics; Gopalakrishnan and Ganeshkumar, 2013). As a result of these studies, it has been concluded with a high consensus rate that social constructivism is the most effective theory that can best suit and explain the essence of STEAM education (Prawat and Floden, 1994). There are seven research papers that are mostly cited by the research milieu that there are very important strategies that explain STEAM in accordance with social constructivism: Clark and Ernst (2007); El-Deghaidy et al. (2016); El-Deghaidy et al. (2015); Guzey et al. (2016); Riskowski et al. (2009); Satchwell and Loepp (2002); Shahali et al. (2017); and Wang et al. (2011). Within the framework of these seven studies social constructivism is considered to be the sole approach to be integrated as a philosophy into STEAM education. Their utterances has accumulated to pinpoint that social interaction is inevitable for successful organization and formation of information (Driver et al., 1994; Eastwell, 2002). This is especially depended on the social aspect of social constructivism where students find opportunities to construct information and synthesize through communication and practice rather than being passive receiver of information (Prawat and Floden, 1994).

2.5 Approaches Associated with Integration of STEAM in Educational Settings

This dissertation study establishes a framework that aims to contribute to the struggles experienced in the process of implementing STEAM education in educational systems. For this reason, the current work will provide instructional strategies for the application of STEAM education under the umbrella of social constructivist perspective. In line with the notion mentioned here, three considerable approaches were eliminated and will be considered in this regard are as follows. These strategies are also considered as the key figures to solve some critical issues that are mentioned by the related literature.

Approaches to STEM integration are discussed theoretically in 3 basic teaching approaches. Those are:

1. Multidisciplinary Integration or Thematic Integration: Students learn concepts and skills separately in each discipline but in reference to common theme. For example, a) Concepts the individual disciplines by organizing the curriculum around a common theme such as “Ocean”, ”Ecosystems”, ”Flight” or ”Pirates”, b) Coherent learning experience, c) Different ways to learn about a topic, d) Defining teaching standards, e) Knowing students’ interests. Negative aspect of this integration is that theme is the only connection between disciplines.
2. Interdisciplinary Integration: Students learn concepts and skills from two or more disciplines that are tightly linked so as to deepen knowledge and skills. For example, a) Teachers organize the curriculum around common learning across disciplines, b) Learning goals from two disciplines are fused to form a single key concept or skill, c) Deeper level of understanding, d) Not entirely

distinct from multidisciplinary integration, e) Differ in degree, f) Identifying disciplines not as significant.

3. Transdisciplinary Integration: By undertaking real-world problems or projects, students apply knowledge and skills from two or more disciplines and help to shape the learning experience. For example, a) Real-world problems or projects students apply knowledge and skills from two or more disciplines, b) Relevant problems and projects, c) Organize curriculum around student questions and concerns (Thibaut et al., 2018)

2.5.1 STEM Practices Schedules with Using Interdisciplinary Integration

Instructional objectives should match with teaching model. Instructional design is a systematic process aimed at helping student learn more easily. Previous researchers reported that an efficient instructional design greatly increases students' success (McArdle, 1991). Many researchers also pointed out that efficient teaching and learning of any topic depends on the teaching methods (Mahajan and Singh, 2003). At this point, teachers should use multiple teaching strategies and methods during instruction as it is needed to increase the cognitive learning of the students in different styles. The findings of the previous studies proposed that the use of the multiple methods by the teachers with flexibility, and enhanced activities to be appropriate for different learning style (source). Various studies have also shown that to be effective in teaching process, instructional design must consider the learners' characteristics, content organization, instructional strategies, and evaluation (Zheng and Smaldino, 2003).

Within this framework, teacher should possess sufficient knowledge of some process practices about how to design an effective lesson schedule. The learning permanency is increased with using the Engineering Design Process, mathematical thinking logic and technological perspectives with STEM lesson (Fioriello, 2010). Teacher should know the process practice of each main discipline.

STEAM Discipline: Science and Engineering Process-Practice

- Asking questions (for science) and defining problems (for engineering).
- Developing and using models with alternatives.
- Planning and carrying out investigations.
- Analyzing and interpreting data.
- Using mathematics and computational thinking.
- Constructing explanations (science) and designing solutions (engineering).
- Engaging in argument from evidence.
- Obtaining, evaluating, and communicating information.

STEAM Discipline: Mathematical Thinking Logic- Practice

- Make sense of problems and persevere in solving them.
- Reason abstractly and quantitatively.
- Construct viable arguments and critique the reasoning of others.
- Model with mathematics.
- Use appropriate tools strategically.
- Attend to precision.
- Look for and make use of structure.
- Look for and express regularity in repeated reasoning.

STEAM Discipline: Technology Process-Practice

The international definition accepted of technology is “Any modification of natural world made to fulfill human needs or desires” (National Resource, 2018)

- Become aware of the technological systems on which society depends.
- Learn how to use new technologies as they become available.
- Recognize the role that technology plans in the advancement of science and engineering.
- Make informed decisions about technology given its relationship to society and the environment.

STEAM Discipline: Mathematics Art Process-Practice

Math and art go together like peanut butter and jelly! You just have to know where to look and be a little creative in creating lessons that are meaningful for both content areas. You never want to sacrifice the skills and processes in either area when creating an arts integration or STEAM lesson.

- Graphing art
- Composite figures
- Geometric shapes of different shapes
- Explore symmetry
- Elements of art, music, theater, design or dance
- Media arts standarts.

School doesn’t have to be a place, but rather a frame of mind that uses the Arts as a lever to explosive growth, social-emotional connections, and the foundation for the innovators of tomorrow.

According to related researches on practical and theoretical framework, teacher should prepared following key questions phase during prepared the STEAM lesson plan. According to answers of these questions, teacher define the students' STEAM key words and concept map of main topic. 5 key questions phase were preparing for designing project-based STEM learning outcomes.

1. Engage Phase-Ask it; what? Focusing to main topic.
2. Explore Phase-Solve it; How? Giving some details, not all.
3. Explain Phase-Design it; is it? Discovering new ideas.
4. Elaborate Phase –Test it; which is? Applying findings and discuss alternatives.
5. Extensions Phase-Improve it; When? Present learning outcomes and link different.

2.5.2 STEAM Strategies for Implementations

STEAM education isn't just one thing-it's a range of strategies that help students apply concepts and skills from different disciplines to solve meaningful problems. Most educators are familiar with the acronym-STEAM, but many have questions in STEAM strategies for implementations (Vasquez, et.al, 2013).

Some questions from teachers who practices STEAM education at different grades in different countries are. 1. Why is STEAM education important and how to practice in lesson plan? 2. Is it for all students, or just for math – and science- oriented students? 3. Can it improve my teaching? 4. Is this just one more add-on to my already packed curriculum?

In response to the curious questions, what to consider when implementing the STEAM education strategy: i) Identity or identify content standards, ii) Identity big ideas & key concepts, iii) Identity essential questions (driving questions), iv) Establish what the students know and be able to do, v) Create multiple and ongoing assessment opportunities throughout the learning experiences, vi) Design Transdisciplinary or interdisciplinary learning activities with project based learning (Wang et al., 2011).

2.5.3 STEAM Lesson Fundamentals and Project Based Learning (PBL)

STEAM Curriculum Specialist Nancy Tsupros defines STEM more specifically as follows:

Students apply science, technology, engineering, and math in contexts that make connections between the classroom, the community, the workplace, and the global enterprise through STEAM education, an interdisciplinary approach to learning that enables the development of STEAM literacy and, with it, the capacity to compete in the new economy. (Tsupros, et al., 2009).

Based on the related literature review of theoretical and practical framework and the findings of related articles and recommendations, STEAM was developed to promote a stronger emphasis on science and math courses in order to prepare future workers for high-tech positions. This cannot be achieved by merely employing technology to teach science and math. Changing our approach to these disciplines is the goal of STEAM. It is about preparing children for life after school and for the real world.

STEAM principles can be incorporated in a variety of ways to produce dynamic, interactive, and collaborative classes that impart real-world skills. Here are eight excellent methods for creating STEAM lesson plans (Palou, 2016; Salinger & Zugo, 2009).

1. Incorporate hands-on activities into your activities. Learning should be done through hands-on activities. They ought to center on action. Students should

ideally work together to answer the challenges and get a deeper, more involved understanding.

2. Use technology to make activities better. Make use of it or utilize it! There's more to using technology than merely teaching a lesson. It entails integrating technology into the lesson in a way that enhances learning and raises the bar for the activity.
3. Adhere to the engineering design methodology. Teams can solve challenges by using the phased engineering design method. According to section 2.3.5, the procedure is cyclical, which means that it is repeated as many times as necessary to arrive at the intended outcome.
4. 4. Promote and facilitate teamwork. The capacity for teamwork is an essential quality.4. Encourage and enable collaboration. The ability to work together is a trait necessary for success in STEAM activities and in life. Learning how to collaborate successfully allows for deeper learning and helps students gain valuable life skills.
5. Select issues from real life. For pupils to develop real-world solutions, STEAM classes should center on real-world issues.
6. Maintain the attention of the entire class. Ensure that all pupils are engaged in related STEAM lessons and activities. In STEAM, inclusivity and teamwork are key components. Every team member ought to take part and look for shared interests to pursue.
7. Strengthen science and math requirements. Look for practical tasks and exercises that relate to math and science curriculum. This will guarantee that the curriculum being taught to students is in line with the Common International Standards.

8. Encourage pupils to come up with several solutions. Solving problems is an important part of STEAM, but make sure your pupils don't think there is just one right answer. Even if it can be challenging to go deeper to the next level, consider some methods. Students are motivated to learn and be innovative when they are faced with challenges.

With these stages, the teacher will keep the student in the center of the learning process, that is, students are “in front of the learning stage” during all teaching and learning process.

As educator, know how an important STEAM learning is to ensure our students succeed not just in the classroom, but out in the real world as well. Students need to develop themselves for life beyond the classroom as tomorrow’ engineers and innovators. According to Jolly (2016); Çevik (2018); Han, Capraro and Capraro (2014) emphasized STEAM and project-based learning (PBL) fundamentals are closely connected. In fact, well-implemented STEAM projects generally require a PBL approach. That leads to this question from teachers if I’m doing PBL, am I doing STEAM? The short answer is – maybe or maybe not. STEAM cannot happen without PBL, but PBL can happen without STEAM. Implementing PBL projects doesn’t ensure that the PBL elements focus on STEAM essentials. The next question, then, is usually: “How does STEAM-based PBL differ from traditional PBL? How can I be sure I’m leading a strong STEAM-based PBL program?” STEAM-based PBL includes traditional PBL Design Elements which turns to meet STEAM criteria. PBL Elements are defined to see how teachers can incorporate them into a STEAM-focused classroom. These elements are:

1. Focus on significant content. All PBL projects focus on students gaining key standards-based knowledge and skills by focusing on fewer concepts and deeper understandings.
2. Determine the skills required for 21^{st} century for betterment of education. Today's world requires some critical skills to analyze, synthesize and finally solve problems by providing creative solutions for the problems and this can be done by implementing problem based approaches into the field of education. Therefore, STEAM, with its understandings and surrounding school of thoughts is the way to create an educational context where individuals can be educated in such a way that can cater the needs of societies with strategies to solve problems. Although it takes time to integrate and have it work for the well being of societies, consecutive approaches will help develop the adaptation of this system in time. Collaboration and cooperation that are consecutive specifics of STEAM approach will work to figure out and create communal solutions for communal problems.
3. Tasks should be created from life spans of students so that they will find many things from themselves and be interesting. With meaningful life problems, students will be enabled to make a link between what is being practiced in schools and what is happening out side of the schools and their connections.
4. Students' thoughts, concerns and interests must be concerned. Students should be provided with several opportunities to make their own choices regarding the type of problem being investigated and worked on. By this way, this will create a more active classroom where students will be engaged in communication and interaction to figure out how to solve the targeted problems. STEAM approach, in this regard, will play a crucial role in establishing a set for students to solve

problems in a creative communal environment. The vital feature of problem based approach with respect to the application of STEAM approach is its unique effect on students' realization of the problem to be studied.

5. Enable students to be involved in research. For students to generate solutions to problems they need to conduct research and find possible solutions through related literature; therefore, they need to be provided with opportunities to conduct research through different resources and find the most suitable resources to collect and analyze information as a part of problem solution process.
6. Provide feedback and suggestions. Problem based learning processes require robust attention and assistance for students who work on a project. The corresponding teacher should continuously assist students wherever and whenever needed. As a sole role of teacher, guidance is crucial in problem based approaches for students to get to know when to use and how to use information in various different ways to make synthesis and form new ideas. For this very reason, the quality of feedback provided by the teacher plays important role in enhancing their understanding of the problem and finding out possible solutions. STEAM approach which is supported by problem based learning strategy is corresponded with cooperation and effective communication not only among students but also among students and teachers. Teachers, in this case, are objected to self-development for the purpose of denoting students with effective feedback.
7. Produce communal results. Students should understand and demonstrate the link between classroom and society. The results of any study should be elaborated for its contributions to the society out of the classroom environment.

The findings should not be disconnected from society since the essence of problem-solving approach involves solving real life problems in accordance with preliminary defined social needs. Therefore, the results should be communal and need to be interest the community.

2.6. 5E Instruction Model in STEAM Classroom

Engage Phase: Getting the student involved in the learning task is the first step. The learner concentrates intellectually on a thing, issue, circumstance, or occurrence. This phase's activities must to link to previous and upcoming ones. The linkages can be conceptual, procedural, or behavioral, depending on the learning goal. Engaging pupils and keeping them focused on the educational activities can be accomplished through questioning, problem definition, demonstrating a disparate event, and role-playing a difficult scenario. Presenting a situation and identifying the instructional task are the teacher's responsibilities. The activity's guidelines and protocols are also established by the teacher.

Table 1: The Roles and Expected Behaviors in Teaching Learning Processes

The Student	Explain Activities	The Teacher
• Asks questions such as: • Why did this happen? • What do I already know about this? • What can I find out about this? • Shows interest in topic. • Responds to questions demonstrating their own entry point of understanding	• Initiate the learning task. The activity should make connections between past and present learning experiences and anticipate activities and organize students' thinking toward the learning outcomes of current activities. • Generate interest • Access prior knowledge	• Raises questions and problems. • Elicits responses that uncover students' current experiences. • Generates interest. • Generates curiosity.

Phase of exploration: After students are engaged by the activities, they require time to ponder over their concepts. The purpose of exploration activities is to give every student a shared, tangible experience from which to further develop ideas, procedures, and abilities. The pupils should be able to relate to and engage with this phase. The purpose of exploration activities is to create experiences that educators and learners can utilize at a later time to formally introduce and talk about concepts, procedures, or abilities related to a certain subject area. The pupils have time to investigate items, happenings, or scenarios during the activity. Through their cognitive and motor engagement in the task, the kids build connections, notice trends, pinpoint factors, and inquire about occurrences. During the exploration phase, the teacher's primary responsibility is to choose activities that result in significant concept building. Thus, the teacher's job is to be a coach or facilitator. The instructor starts the exercise and gives the pupils time and freedom to research things, materials, and circumstances according to their individual theories and observations. When needed, the instructor can help students come up with new explanations by providing coaching or guidance.

Table 2: The Roles and Expected Behaviors in Teaching Learning Processes

The Student	**Explain Activities**	**The Teacher**
Thinks outside the box when it comes to the task at hand. • Attempts to find solutions to issues and shares them with others. • Postpones making decisions. • carries out tasks, forecasts, formulates theories, or draws generalizations • Learns to listen well; • Exchanges views and puts judgment aside • Records observations and/or generalizations • Discusses tentative alternatives	Give pupils a shared foundation of experiences from which to identify and develop contemporary concepts, procedures, and skills. • Gain knowledge about important ideas • Acquire novel proficiencies • Examine, enquire, and challenge encounters • Analyze their perspectives. • Build rapport and comprehension	Elicits answers that reveal pupils' present level of understanding of the idea or subject. • Brings up issues and queries. Facilitates learning by watching and listening to students as they engage and by providing thoughtful, inquiry-based questions. • Sparks curiosity. • Sparks interest.

Explain Phase: The act of making ideas, procedures, or abilities simple, understandable, and evident is known as explanation. The explanation process gives the teacher and students a common vocabulary related to the learning process. During this stage, the instructor focuses the students' attention on particular facets of the engagement and discovery activities. The instructor starts by asking the class to explain themselves. Secondly, the instructor presents explanations in an authoritative and straightforward way. The purpose of explanations is to provide a common language and structure for the exploratory experiences. The first portion of this phase should be based on the explanations provided by the students, with a clear connection made between the explanations and the experiences from the engagement and exploration phases of the instructional approach. Presenting ideas, procedures, or abilities in a condensed, straightforward, and understandable manner is crucial to this step. After that, move on to the next.

Table 3: The Roles and Expected Behaviors in Teaching Learning Processes

The Student	**Explain Activities**	**The Teacher**
Explains to other pupils potential alternatives or responses. • Pays close attention to the arguments made by other pupils. • Contests explanations given by other pupils. • Listens to and tries to comprehend explanations offered by the teacher. • Refers to previous activities. • Uses recorded observations in explanations. • Uses previous observations and findings • Provides reasonable responses to questions	Draw students' attention to a specific area of their engagement and exploration experiences and provide them chances to show off their actions, process abilities, or conceptual knowledge. This phase also provides opportunities for teachers to introduce a concept, process, or skill. • Connect prior knowledge and background to new discoveries • Communicate new understandings	It provides definitions, justifications, and fresh language. • Bases concept explanations on prior experiences of the pupils. • Encourages students to explain their observations and findings in their own words • Provides definitions, new words, and explanations • Listens and builds upon discussion form students • Asks for clarification and justification • Accepts all reasonable responses

	• Connect informal language to formal language	

Phase of Elaboration: After students have received an explanation of their learning assignments, it is crucial to include them in further activities that expand, apply, or elaborate the ideas, procedures, or abilities. It's possible that certain pupils still hold misconceptions or that their understanding of a concept is limited to the exploratory experience. Additional time and experience gained by elaborate tasks aid in learning. Students should get the chance to apply what they have learned in novel settings, according to the instructor.

Table 4: The Roles and Expected Behaviors in Teaching Learning Processes

The Student	Explain Activities	The Teacher
Applies fresh terminology, definitions, justifications, and abilities to novel yet comparable circumstances. • Asks questions, suggests solutions, makes decisions, and designs experiments based on prior knowledge. • Uses evidence to support reasonable judgments. • Offers logical conclusions and remedies • Keeps track of observations, justifications, and fixes	Students' conceptual knowledge and abilities should be stretched and challenged. Students gain more knowledge, appropriate skills, and a deeper, wider understanding through new experiences. • Use what you've learned in a novel or comparable circumstance. • Expand on and clarify the idea under discussion Use formal words to convey your newfound understanding.	expects pupils to use previously given definitions, definitions, and explanations in new contexts. • Encourages pupils to use the knowledge and abilities in novel contexts. • Brings up and directs students to other possible explanations. • Enhances new learning by utilizing knowledge that has already been mastered. • Motivates pupils to put the new knowledge and abilities to use. encourages pupils to apply concepts and terms they have already learned

Phase of Evaluation: It's critical that students eventually get input on how well their explanations fit the context. Informal assessments might start at the outset of the instructional process. Following the elaboration stage, the instructor might finish a formal evaluation. Teachers need to evaluate student learning outcomes as a matter of practical education. During this stage, educators conduct formative or summative assessments to ascertain each student's comprehension level. Additionally, this is a crucial chance for students to assess their comprehension and apply the skills they have learned. Additionally, the teacher assesses whether or not the students have met the performance indicators at this point.

Table 5: The Roles and Expected Behaviors in Teaching Learning Processes

The Student	Explain Activities	The Teacher
Demonstrates an understanding or knowledge of concepts and skills. • Answers open-ended questions by using observations, evidence, and previously accepted explanations. • Evaluates his or her own progress and knowledge. • Asks related questions that would encourage future investigations. • Provides reasonable responses and explanations to events or phenomena	Encourage students to assess their understanding and abilities and provide opportunities for teachers to evaluate student progress. • Demonstrate understanding of new concept by observation or open-ended response • Apply within problem situation • Show evidence of accomplishment	Assesses students' knowledge and skills. • Observes students as they apply new concepts and skills. • Looks for evidence that students have changed their thinking. • Allows students to assess their learning and group process skills. • Asks open-ended questions such as, Why do you think...? What evidence do you have? What do you know about the problem? How would you answer the question? • Encourages students to assess their own learning

(Based on the 5E Instructional Model presented by Dr. Jim Barufaldi at the Eisenhower Science Collaborative Conference in Austin, Texas, July 2002. Adapted from description by Cornel University, 2005, Achieving Scientific Literacy by Rodger w. Bybee, Heinemann, Portsmouth, NH, 1997).

2.7 STEAM Oriented Lesson Plans

STEAM essential lessons provide all the tools and strategies. The aim of the essential or driving questions is help to teachers for better understanding different teaching approaches to STEAM integration. At this point the following essential questions help us to understand "How to implement authentic STEAM teaching and learning into your classroom?

With using the interdisciplinary Integration to design NC STEAM Model lesson plan Students learn concepts and skills from four disciplines that are tightly linked so as to deepen knowledge and skills. Teachers organize the curriculum around common learning across disciplines science and Technology, learning goals from four disciplines are fused to form a single key concept or skill.

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Table 6: "STEAM Lesson Plan"; Schedule Approach to STEAM is Designed by the Applying Interdisciplinary Teaching Approach

STEAM LESSON PLAN	
A. Lesson Plan Framework	
Lesson: Science-Technology	**Duration:** 2 weeks. 1.Semester 9-10 Week **Class**: Grade 4 Red
STEAM Common Theme: Green Energy *(Theme topic is decided beginning of the semester with all lesson teacher. As a result of each lesson's small projects are combined to final big project end of the semester.)*	**STEAM Project Topic:** Solar System *(All grade 4 teachers are decided together beginning of the semester that is related with common theme topic. Each lesson teacher combines their projects on the common theme they set at the beginning of the semester.)*
Essential Question on theme: "How can we improve solar system efficiency?" *(All lecture teachers' common questions thought out to topic. Each teacher starts to lesson with this essential question.)*	
Define a Real-life Problem Statement with related essential question: One of the environmental and health problems experienced is power plants. Due to this problem, the demand for solar electricity systems is increasing all over the world**.** *(Problem statement should be to relate with above essential question for critical thinking)*	
SMART STEM Project **S**pecific topic on STEM topic, Project should be; **M**easurable interdisciplinary learning outcomes, **A**vailable content with relating main lesson , **R**eachable goals, **T**ime-bound project based lesson)	Title: "SMART SUN IN MY HOUSE" Project committee: Lecturer and students name
STEAM Literacy and Key Words	
Common Learning outcomes-STEAM Disipline-STEAM Concept Map on related define real life problem statement.	Science literacy key words: Green Energy **S**: Give weather report from different sun rays time. Technology literacy key words: Innovation, online control, performance report **T**: Ideas and invention with using different technological tools Engineering literacy key words: Solar System, Saving **E**: Designing sun panels' mountings and saving electricity. Mathematics literacy key words: Fractions, Angles, numbers**.** **A:** Draw best portative panel design and connections-estethics **M**: Energy transfer in different design models (fractions, angel)

	"Asking questions for science, defining problems for engineering, solve it with mathematics process, imagining with technology."
Main Core Learning outcomes **Cognitive Domain (CD1)** **Affective Domain (AD2)** *(Students' learning outcomes are listed according to the cognitive and affective domain in the related course.)*	CD 1.1. Students will learn new innovation why is the solar system an important today. CD.1.2. Students will learn the efficient of different time of sunlight angels. AD.2.1. Students will learn the benefit of energy saving
Social Learning Outcomes *(Learning outcomes are written in the context of student social responsibility)*	Students will learn the importance of healthy environment. Attention is drawn to the health of all living things, not just humans.
Useful Materials *(The materials and technologies should be that you plan to use throughout your lesson are affordable, reasonable and accessible under the conditions of your school)*	Films, posters, newspaper,
Sources *(Apart from textbooks, relevant and reliable websites with full addresses; basic textbooks or foreign sources)*	Handouts with the basics of the two lessons (Mathematics, Science), web page, and references related studies and projects
Out of Class Activity	Group working, out of class observation, interview with people who install solar system
Related Professions, Duties and Responsibilities *(Professional information is provided to the students by explaining the professional occupation definition, duties and responsibilities of the related subject About STEM as well as today's future professions suggest to your students. In this way, students are provided both to learn about professions and to be aware of their individual strengths.)*	Electrical engineering, graphic designer, salesman, international trade specialist

THE 5E Model of INSTRUCTIONAL DELIVERY
What should be happening at each stage?

5 E Definition	**Teacher Behavior**	**Student Behavior**
1.ENGAGE		
Generate interest Access prior knowledge Connect to past knowledge	Motivates Creates interest	Attentive in listening Ask question

Set parameters of the focus Frame the idea	Taps into what students know or think about the topic Raises questions and encourages responses	Demonstrates interest in the lesson Responds to questions demonstrating their own entry point of understanding
2.EXPLORE		
Experience key concepts Discover new skills Probe, inquire, and question experiences Examine their thinking Establish relationships and understanding	Acts as a facilitator Observes and listens to students as they interact Asks good inquiry-oriented questions Provides time for students to think and to reflect Encourages cooperative learning	Conduct activities, predicts, and forms hypotheses or makes generalizations. Becomes a good listener Shares ideas and suspends judgment Records observations and/or generalizations Discusses tentative alternatives
3.EXPLAIN		
Connect prior knowledge and background to new discoveries Communicate new understandings Connect informal language to formal language	Encourages students to explain their observations and findings in their own words Provides definitions, new words, and explanations Listens and builds upon discussion form students Asks for clarification and justification Accepts all reasonable responses	Explains, listens, defines, and questions Uses previous observations and findings Provides reasonable responses to questions Interacts in a positive, supportive manner
4.EXTEND/ELABORATE		
Apply new learning to a new or similar situation Extend and explain concept being explored Communicate new understanding with formal language	Uses previously learned information as a vehicle to enhance additional learning Encourages students to apply or extend the new concepts and skills Encourages students to use terms and definitions previously acquired	Applies new terms and definitions Uses previous information to probe, ask questions, and make reasonable judgements Provides reasonable conclusions and solutions Records observations, explanations, and solutions

5.EVALUATE		
Assess understanding (Self, peer and teacher evaluation) Demonstrate understanding of new concept by observation or open-ended response Apply within problem situation Show evidence of accomplishment	Observes student behaviors as they explore and apply new concepts and skills Assesses students' knowledge and skills Encourages students to assess their own learning Asks open-ended questions	Demonstrates an understanding or knowledge of concepts and skills Evaluates his/her own progress Answers open-ended questions Provides reasonable responses and explanations to events or phenomena
MEASUREMENT and EVALUATION		
Measurement Process-oriented assessment	1.Diagnostic	1. Identification of students' prior knowledge level.
	2.Formative	2. Midterm exams, in and out of class, presentations etc.
	3.Summative	3. Final exam, project performance, reports etc.
Evaluation Performance-oriented assessment	Performance oriented development assessment according to scores of formative and summative evaluation	Level definitions according to the national achievements that must be obtained with the related course and STEM education. This level will show the student's identifying level in the next semester

2.8 Mathematics, Technologies, and Critical Thinking

People have used educational tools to meet all of their demands for growth and adaptation throughout history. People who are industrious and always improving themselves are valued in our society. At this point, mathematics plays a crucial part in people's ability to formulate and solve issues, think critically and independently, project confidence, and explain cause-and-effect relationships.

An analysis of mathematics curriculum is conducted by the IEA (International Educational Achievement) study, which highlights the importance of math education globally.

In the educational curriculum, mathematics is a core subject. In most educational systems, students spend between 12 and 15 percent of their time studying mathematics. The only other subjects that receive this much attention are those related to language, especially reading and one's mother tongue. The essential role that mathematics plays in modern society is reflected in the curriculum's emphasis on the subject. Fundamentally, understanding mathematical ideas and methods is essential for success in the fields of science, engineering, and business. From a social standpoint, mathematical proficiency is necessary to guarantee the continuous creation of the highly qualified workers needed by industry, technology, and science as well as to prepare a numerate populace. It is essential to an efficient education, even outside of these pragmatic reasons. It offers an illustration of clear, beautiful, abstract thought. (Traves, Westbury, 1989; 1).

To contribute to the creation of original goods and answers to difficult issues, students must acquire and apply 21st century talents with confidence. The four Cs are the fundamental 21st century abilities that students must acquire: i) Collaboration or working with others to accomplish a task. ii) Communication: exchanging ideas, solutions, queries, and thoughts. iii) Creativity: creativity and invention result from attempting novel methods to accomplish tasks. iv) Critical thinking or approaching issues from a fresh angle. connecting learning across disciplines and subjects.

Technology and engineering that is integrated into education is one of the best ways to enhance student performance in education (Brophy, et al., 2008). Scientific methodology has revealed that the integration of technology especially enhances the performance of students in other disciplines as well (NRC, 2012; Bethke, et al., 2008). One other important concern of the related literature is that the activities generated for STEAM applications must be enjoyable for students (Koszalka, Wu, & Davidson, 2007). Although it varies from teacher to teacher, the inclusion of enjoyable activities into STEAM applications requires creativity on the part of the teacher (Lim, Zhao, Tondeur, Chai, & Tsai, 2013; Tondeur, Cooper, & Newhouse, 2010).

There are many researchers conducted to maintain the importance of inclusion of technology in education and the findings of these researches have pointed out that the success of students have been significantly increased in other disciplines as well (e.g., Kulik & Kulik, 1991; Machin, McNally, & Silva, 2007). In addition, some other studies reported that a significant number of students performed much better in all subject matters when the use of technology has been increased in educational applications (e.g., Ehri, Dreyer, Flugman, & Gross, 2007; Torgesen, Wagner, Rashotte, Herron, & Lindamood, 2010). However, some other researchers added that the long terms sustainability regarding the projection of success of these students are unknown and further investigations needed for better understanding of the concept. The most criticized side of such applications is that not all school environments have the same technological conditions to apply in their educational contexts. Indeed, what is more appealing is that researchers all over the world the have adapted their projector to pinpoint the learning outcomes that changes the actual projector of education from being passive to active one. For that reason one to one integration with personal laptops have been provided to students in many high school within the scope of a research supported my many international agencies (e.g., Lowther, Inan, Ross, & Strahl, 2008; Silvernail, Pinkham, Wintle, Walker, & Bartlett, 2011). However, further research is inevitable to gather better insight into the understanding of the optimum application of technology and integration of engineering into education.

Mathematics on the other hand has been considered as such a discipline that already exists in individuals to some extend without any extra formation of input (Houssart, 2001). What is needed is effective pedagogical procedures that will be handled by effective teachers to let students face with their own abilities in mathematics (Morgan, Farkas, & Wu, 2009; Princiotta, Flanagan, & Germino Hausken, 2006). There are many studies supporting that students can achieve core mathematical foundations at early ages if they were provided with true applications with decent education approaches (Duncan & Magnuson, 2011; Jordan, Kaplan, Ramineni, & Locuniak, 2009). Because, they believed that the early years of learning, including Kindergarten, are critical periods of life of an individual within which they build an understanding of mathematical concept at the first place.

There are many other studies which mention the use of authentic practices for the inclusion of STEAM approaches within the mainframe of mathematics (NGSS, 2013). Some other researchers advocated that students who are engaged in authentic scientific environments in a more collaborative environments become more successful in their full careers (Bricker & Bell, 2008; NRC, 2012). Authentic research environments also create a classroom atmosphere where students are more motivated to solve problems (Fang & Wei, 2010; Herrenkohl & Guerra, 1998). In particular, pedagogies that are illustrated with mathematical concerns should be designed in a way to merge classroom and society (Sandoval & Morrison, 2003). This approach is explained to be effective in enhancing students' ability to analyze, synthesize and evaluate situations from different perspective to create solutions to defined problems (Ebenezer, Kaya, & Ebenezer, 2011). However, it is inevitable to state at this point that to bring this ideal in to being, schools need qualified teachers who were trained in an expected way. A consideration of the role of the teacher in STEAM education is discussed in the following section.

As a summary after the related literature reviews, "*Critical thinking isn't just a skill, it is a guide to good-decision making for successful life. STEAM education is the most important foundation for critical decision making and success.*"

Chapter 3

METHODODOLOGY

3.1 Introduction

This chapter will present the methodology and the procedure of the study. It covers the research design, population and sample, the instruments, data collection procedure, and the data analysis procedure.

3.2 Research Design

Based on the cause and effect and causal-comparative nature of the study, quasi-experimental research with experiment and control groups was designed to test the effects of the defined exogenous variable (A Sustainable Progressive STEAM Model) on the defined endogenous variables (CTDs and Mathematics Achievement). As an exogenous variable, a sustainable progressive STEAM education model was taken as the main treatment strategy. Since a relatively newly designed approach was being tested, applicators, who were teachers of 5th graders, were enrolled in an in-service teacher training program prior to any application of pre-test and post-test applications. The ingredients of the so-called in- service teacher training program aimed to prepare applicator teachers for the experiment by denoting them with all the necessary knowledge and experience regarding the SP-STEAM education model, preparation of lessons, measurement, and evaluation. This research was designed in a way that ensures the control of most of the variables that might possibly be affecting the results of the experiment. For this reason, most of the extraneous variables were extracted and evaluated carefully. For an experiment to be truly valid and reliable, the selection of participants and research settings played crucial roles (Cash, et al., 2016). In order not to cause any deficiencies regarding the reliability and validity of the experiment, all precautions suggested by the pioneers of the field were followed inclusively (Cash, et. al, 2016).

3.3 The Experimental

3.3.1 The Sustainable Progressive STEAM Model

When the Ministry of Education of North Cyprus clearly explained the long-term objectives of the national education, a special quotation opened for the sustainability of problem solving skills among children. For this reason, the SP-STEAM model was developed especially for primary school students to help and guide them, nurture their critical thinking dispositions, and develop their academic achievements in mathematics. Starting with the term sustainability, we not only expect our children to develop positive attitudes toward critical thinking and elicit high academic grades but also want them to maintain these skills throughout their academic careers and succeed in life in the long term. The term sustainability in our research has two levels. Sustainability is considered at the macro and micro levels. At the micro level is the sustainability of a systemic approach at the schooling level, whereas; sustainability at the macro level refers to the successes of individuals who have graduated from an educational system. For the latter, it is too early to make inferences; but for the former, this research will create a basis for further negotiations. The sustainability of any gained positive experience is understood to be crucial for further educational and professional careers of children and youth (Geng, Jong and Chai, 2019; Siew, Amir and Chong, 2015; Wang, Moore, Roehrig and Park, 2011). That is to say, a treatment model that is not sustainable will fail in the following stages of life, and thus, children will fail to think critically and solve problems. The core element for the sustainability of any given positive experience is characterized by a paradigm shift in the way children think (Akgündüz et al., 2015; Hacıoğlu, Yamaga and Poplar, 2016; Tekerek and Karakaya, 2018). This is also known as habit of mind. If a certain way of thinking has become a habit of mind, then it becomes an inevitable part of a person's thinking, which is where a person begins to establish unique characterological profile to question the universe around them in a unique way (Gonzalez & Kuenzi, 2012). This is especially true if high-quality education is provided to children as early as possible, and this establishes the core of sustainability. In our application of the SP-STEAM model, great importance was given to sustainability. Specifically, a dedicated STEAM instruction approach was developed according to the needs of a particular group of students. We believe that we cannot avoid rote learning by developing a specific approach for a specific group of children. The SP-STEAM Model also has a progressive dimension, which refers to the gradual tracking of each person's performance upon a dedicated scale. For each child, a detailed 10-point dichotomous scale performance tracker was developed. As discussed in length across the following sections of this manuscript, a detailed in-service education was provided to teachers in utilizing this assessment tool. As detailed further, teachers, the applicators of any given school of thought, need to be in a constant state of development in order to keep themselves fresh (Ananiadou, Claro, 2009; Rotherham, Willingham, 2010). For each subject matter and unit in mathematics, this tool was used as supplementary material to guide teachers in the process. Teachers obtained opportunities to guide children's learning, especially where they noticed any obstacles, misconceptions, and struggles that could possibly be experienced by the children. With these means, the children were expected to self-screen their improvements while simultaneously gaining confidence in scientific thinking. On the other hand, it is believed that the teachers would better monitor children's improvements, and provide better feedback in turn. This cyclic progressive approach would enable children to build experience upon experience, finding opportunities to practice and gain a scientific thinking culture. The classroom atmosphere was designed for the experiment groups; thus, student-student, student-teacher, group-group, and group-teacher interactions were enhanced. In the promotion of problem-solving, research-based collaborative techniques were expected to be used by the teachers, in turn establishing an expectancy for the students to practice critical thinking. The detailed schematic expression of such a classroom atmosphere is mimicked in Figure 1 below.

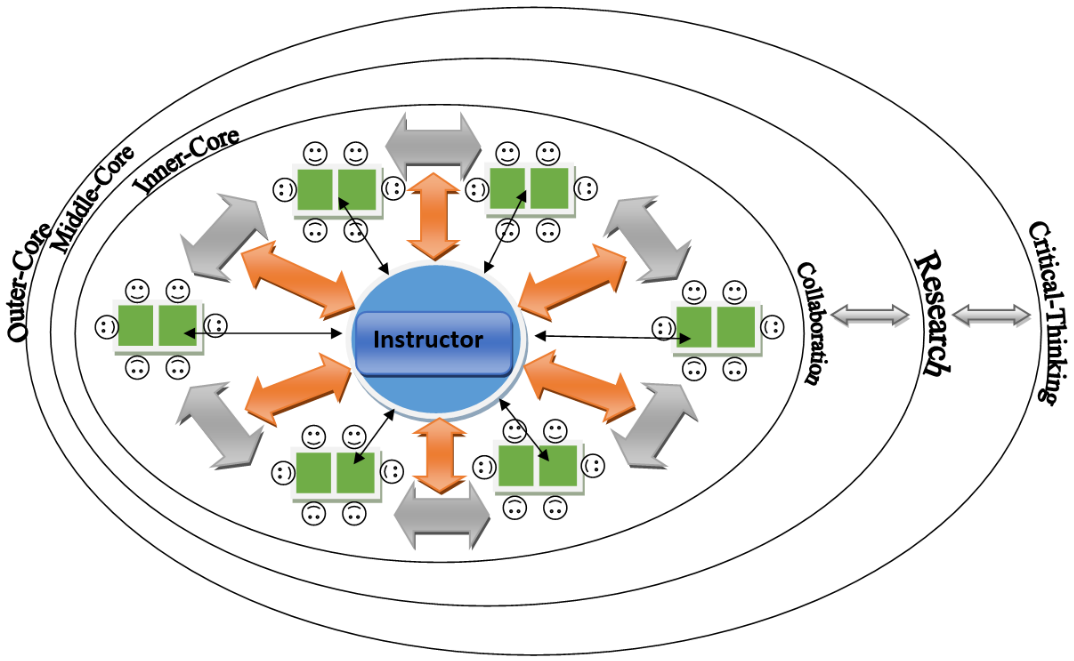


Figure 1: Core Rationale of the SP-STEAM Model

Based on the research context explained above, detailed are some expected outcomes and assumptions, regarding the reasons why the treatment groups are expected to have achieved better than the control groups. The treatment was considered to be done in a classroom atmosphere, where students concentrate on solving life-oriented mathematic problems rather than being passive receivers of information. As explained by the related literature, students, who are encouraged to solve meaningful life problems, are expected to become more successful in mathematics (English & King, 2018; Priatna et. al, 2020; Aini, et. al, 2019; Stein, et. al, 2007). Moreover, it was assumed that the students in the treatment groups were provided with opportunities by the classroom teachers, to clarify and redefine the objectives of the problem, and deal with issues, add context, experiment with materials, and build collaborative group works. It is additionally assumed that they would be reinforced in generating ideas via brainstorming in group discussions. This process was believed to help and guide them in using their potential to formulate, discuss, use different strategies, design, interpret, and evaluate ideas for possible solutions of problems. Such a classroom environment where students were encouraged to develop their own ideas in solving mathematic problems would establish the students as not only being successful in mathematics but would also display high performance in critical thinking (Priatna et. al, 2020; Aini, et. al, 2019; Stein, et. al, 2007). The bulk of the literature highlighted the strong tie between analytic thinking, which is an inevitable facet of critical thinking, and mathematics (Zeid, et. al, 2014; Lee & Lee, 2022; Parlakay & Koç, 2020; Şahin & Ayar, 2014; Yasin, et. al, 2019; Syafril et. al, 2020; Firdaus & Rahayu, 2019).

A school that is denoted with hi-tech science laboratories, technology laboratories, mathematics practice tools, robotic applications, and updated content for subject matters is not enough alone to build a decent critical thinking culture for children and youth (Yasin, et. al. 2020). Highly trained teachers with philosophical perspectives are required, positioning them as good role models for children (Thi, et. al, 2020). Besides the scientific part, the artistic dimension of becoming an effective teacher plays a significant role in this experiment (Nurwahyunani, 2021); hence, the detailed and dedicated training program developed for teachers prior to the application of this dedicated SP-STEAM Model.

3.3.2 Teacher Training Process

The teacher training program was developed and carried out by two independent teacher trainers, who were appointed by the North Cyprus Ministry of Education for a European Union project (Project started at 2014 and the goals of project was developed teachers' teaching strategies and adapted the new education approach), and have more than 10 years experience in providing in-service teacher training for primary school teachers. After obtaining their consent to participate in this study as teacher trainers, the researchers met with the trainers several times, negotiating the expected outcomes of the experiment. As a result of the meetings, a consensus upon the aim and expected outcomes of the teacher training program were reached. Accordingly, the teachers within the experiment groups would be trained in terms of methodology, the materials, and technology they would use during their instructions. The experimental group teachers were informed about the application of problem-solving-based teaching methods and collaboration in teaching mathematics. The training lasted for 5 weeks and included workshops, where teachers practiced linking every subject matter to real life situations, and produced materials for learners to solve mathematic problems. As asserted by several researchers, learning mathematics is more meaningful and interesting if problems are linked to children's living quarters, establishing more enjoyable problem solving (Parlakay & Koç, 2020; Çetin & Şeker, 2022). For this reason, the first and an important facet of the teacher training program, was that teachers were trained to produce examples and activities enjoyable for the learners, so that the problem solving process would be more interesting and appealing. The second facet of the teacher training program was to help teachers create lesson plans to cover the expected outcomes. The lessons were expected to be designed in a way that would enable both the teachers and the students to practice their thinking skills and subject maters in a systematic way. A five phase systematic teaching approach has been developed and introduced to teachers via training and workshops. This five phase systematic teaching approach developed for embedding the SP-STEAM model, is explained in detail in Section 3.3.3 below.

3.3.3 Lessons in Experimental and Control Groups

The lessons within the control groups were delivered as usual. The teachers in these classrooms were not enrolled in any teacher training programs. Both groups followed the same curriculum, however, students in the experimental groups followed a totally different procedure of teaching learning situations. Conventionally, in a majority of the schools in North Cyprus, lessons were held by utilizing direct teaching methods and materials, where students were passive receivers of information, and the teachers were active transmitters, constituting as a motivating point which triggered the conduct of this and similar studies. Within the experimental groups, teachers utilized the SP-STEAM model, where students were provided with opportunities to use their potential, form ideas for problem solutions, and enjoy the practicing of subject matters. The schematic expression of instructions can be seen in Figure 2 below:

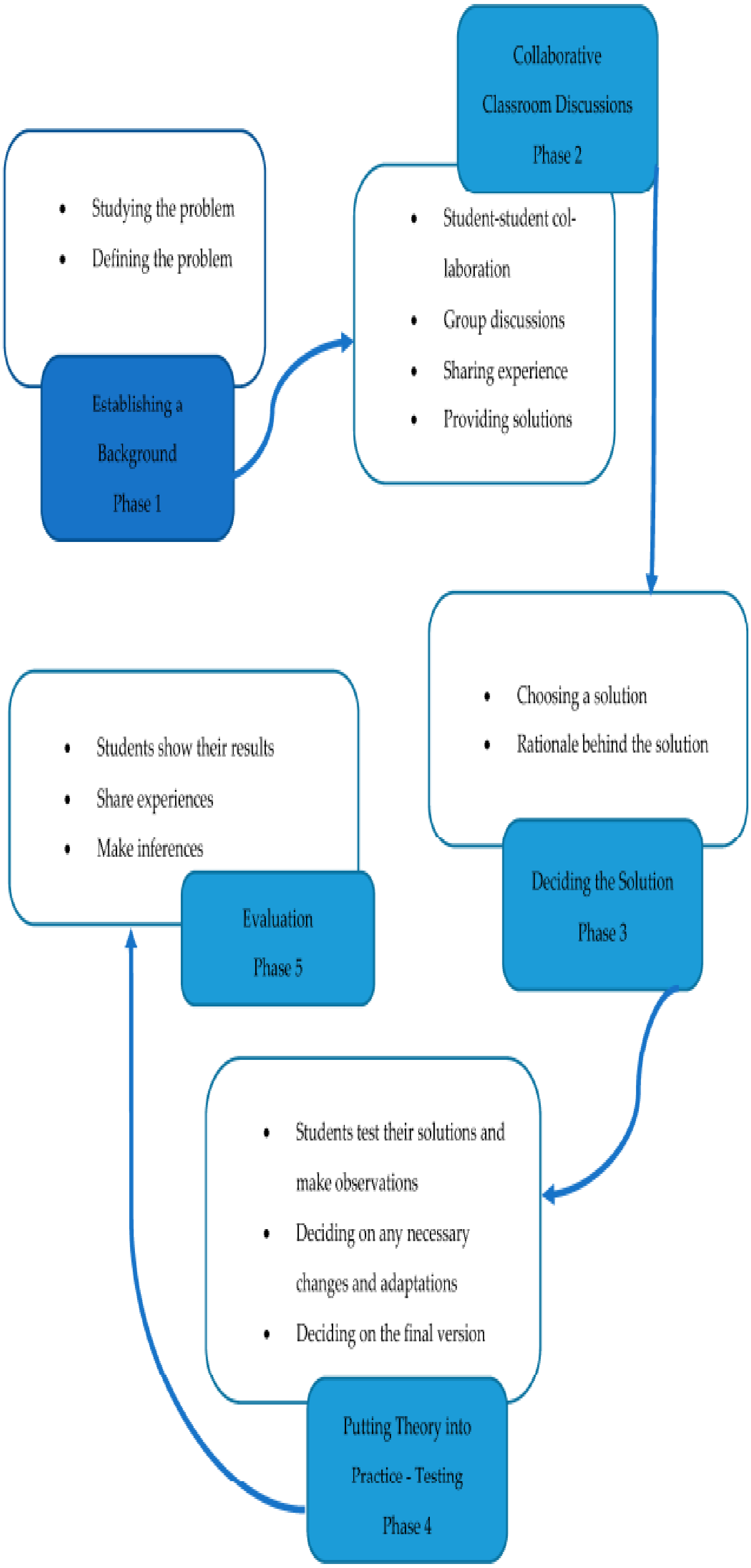


Figure 2: The Schematic Expression of the Flow of The Lessons Applied in the Experiment Groups

The first phase of instruction was establishing a basis for the upcoming phases of instruction, and was thought to be the phase of preparation. Students were given a sample situation where they can generate a problem out of a given situation. The situation was chosen as a real life situation and an attractive one, for enjoyment while working on it. Students, in this phase, were allowed to collect data, discuss, and find a problem to be solved, under the guide of teachers. Students were instructed to work in groups, as can be seen in Figure 1. They were permitted to interact with group members, and with other groups as well. Teachers acted like moderators and guiders. Here, the important point was allowing the students to work together in a collaborative classroom environment, as per the suggestions of many researches, in order to establish a decent SP-STEAM education model (Gulhan & Sahin, 2016; Gillies, 2018; Zeid, et.al, 2014; Aini, et. al, 2019; Carrol, 2014; Çiftci, et. al, 2022; Thi To Khuyen, et. al, 2020; Stein, et. al, 2007). The second phase characteristically shared the same approach as the first phase; however, each group was expected to come up with possible solutions to the problem defined in the earlier phase. They could come up with one solution or more. During the third phase, the students again worked in groups and decided on one solution to a given problem, however; the important element here was to explain the rationale behind the solution they saw to the problem. Choosing a solution means to eliminate other solutions; thus, the point here was to allow students the experience of giving up on something in the knowledge of other existing options and their consequences if they are chosen. As students practice mathematics, they also practice their reasoning abilities via a systematic method of thinking. In this way, they were also expected to practice critical thinking as well. Studies conducted worldwide underline an important dimension of the SP-STEAM education models, especially in teaching mathematics, that unless students find opportunities to practice mathematics without developing a rationale behind any solution to any given problem, students only learn in schools but do not solve problems in life (Priatna, et. al, 2020; Aini, et. al, 2019). In the fourth phase, students presented and displayed how their solutions worked to solve the problem they defined. Here, students could redefine a solution or adapt it to make the solution work better. Finally, at the fifth phase, students summarized their results and made some inferences out of their evaluation of the whole process.

The experimental group lessons generally followed these five phases. Teachers were trained (detailed teacher training process explained in the previous section) to prepare their lessons considering the problem solving sequence as explained in Figure 2. While the experiment groups lesson design was in this innovative format, both the control and experiment groups followed the same curriculum content, with the control groups still using the conventional teaching approaches. The curriculum content, subject matters, and objectives of the primary school mathematics education were prepared by the North Cyprus Ministry of Education and sent to all public and private schools prior to the beginning of each new semester in North Cyprus. The current and renewed curriculum content and objectives can be seen in Figure 3 below. Figure 3, Program Outcomes and Content Domains of the Primary Mathematics Education of North Cyprus for 2021–2022 Spring and Fall Semesters.

General Program Outcomes	Content Domains
Defining the Problem Students will be able to 1. draw a figure expressing the problem 2. create a number of sentences related to the problem 3. detect missing or excess information about the problem 4. examine the logic of the information given about the problem 5. recognize hidden information about the problem	
Strategy Determination and Control Students will be able to 1. collect, organize, and interpret information 2. simplify information 3. use number sentences and select operations 4. develop abilities to guess 5. develop their mathematical reasoning 6. apply modal solutions 7. break problems down into smaller parts 8. use models to solve problems 9. express the result and explain why it is true	• Operations with Natural Numbers • Operations with Fractions • Operations with Percentages • Decimal Notation • Geometric concepts and illustrations • Data collection and evaluation • Measurement • Measuring time • Measuring areas
Communication, Presentation, and Expression Students will be able to 1. explain each step of the problem in detail 2. use appropriate symbols, concepts, and terminology 3. apply grammar rules	
Writing a Problem Students will be able to 1. write a problem in accordance with the given operation(s) 2. write a suitable problem based on a given result 3. write a problem for a given theme/topic 4. complete an unfinished problem	

Figure 3: Program Outcomes and Content Domains of Mathematics Lesson

No restrictions in the distinctive application of these phases were applied, and teachers were permitted to merge some phases according to the flow of their lectures. For better understanding of how these phases generally functioned in real life situations, the following example in Figure 4 can be considered.

Phases	Events
1	1. Students are divided into groups of 3–4 people. 2. Groups are asked to design nests for birds on the trees in the school garden, and the following explanations are made for this purpose: Scientists estimate that there are 10,000 different bird species worldwide. You do not have to go far to see some of the different birds found in nature. You may see them around your home as well. How can these birds survive in difficult conditions? What do they need to live and grow? It is also very important that birds have food, water, and shelter and can breathe. 3. A group discussion environment is created about what to do, and they are asked to write their ideas. They are asked if they watch birds in nature (have you ever watched birds in your garden or playground? What do birds do? etc.) 4. Students are asked to clarify the features of the bird nest they will design. 5. They are asked to draw a sketch on a worksheet. 6. They are asked to create a material list by considering which materials are required. 7. They are asked to plan the design process and report everything they will do step-by-step. 8. They are asked to continue researching until the second stage, clarify their thoughts on the design, and bring the necessary materials to the class.
2 and 3	9. The design plans of the groups and the materials they bring accordingly are examined, and their explanations are obtained. 10. Design processes are monitored and guided. 11. Probing questions (sir, I meant deepening questions) are asked to help them think and look from a broader perspective. For example: How do you think your design meets a bird's basic needs? What parts of your design provide food, water, or shelter for the bird? 12. Groups explain and report what they did and why they did it. 13. They are asked to give the final version of the design and report the features of the design, the materials used, and the points they paid attention to while using it. 14. Until the next stage, they are asked to question their designs, gain opinions from experts, and report.
4 and 5	15. They are asked to explain what they did in the previous stages. 16. They are asked to place the nest on the trees (teacher supported). 17. Groups are observed as they place their designs and asked to examine what they did and why. 18. They are asked to explain their designs to other children in the garden. 19. They are asked to evaluate/discuss the similarities and differences among the designs.

Figure 4: Sample Lesson Flow for SP-STEAM Model Teaching

3.4 Population and Sample

The population for which the results of this study would be generalized is composed of all 5th-grade primary government school students in NC (N = 1200–1500). With respect to the mainframe of this population, the research setting might have been any one of the government schools, which could have been randomly selected from the list of schools. In this scenario, all the schools in the list had an equal chance to be selected as a research setting, with every student in that randomly selected school having an equal chance to be selected as a participant for both experiment and control groups. This is also valid for the applicators, who were the teachers in this case. However, for the current research, pre-existing groups of 5th grade students were selected for both the control and treatment groups, because of the limited research conditions, which turned the experiment into a quasi-experiment research design. The sampling procedure for this experiment yielded two experimental groups and two control groups (4 × 4 pre-post experiment design). Participants were randomly selected to establish the experimental and control groups from all the 5^{th} graders in a public school in NC, with 26 students in each group, making a total number of 104 students. The groups were coded as experiment group 1 (n = 26 with 15 girls and 11 boys), experiment group 2 (n = 26 with 19 girls and 7 boys), control group 1 (n = 26 with 16 girls and 10 boys) and control group 2 (n = 26 with 16 girls and 10 boys).

3.5 Data Collection Tools

The California Critical Thinking Disposition Inventory (CCTDI) (Facione, et. al, 1992) was used to measure 5th-grade primary school students' critical thinking dispositions. This tool was selected because of its grounding in the APA Delphi Report (American Philosophical Association), which has achieved cross-consensus on the conceptualization of critical thinking, its conceptual clarity (Facione, 1990), and its design in measuring different aspects of critical thinking disposition (Facione, 2000). In order to use the CCDI scale, permission was received from the California Academy to apply it to up to 200 people for a fee. Permission document appendix G has been submitted.

As the CCTDI originated in the United States, care was taken to ensure its suitability as an instrument in assessing the same dimensions for Turkish speaking students. A Turkish translation of the CCTDI was tested in the TRNC by Iskifoglu (Iskifoglu, 2014) and was found to be equivalent to the English original in its validity and reliability. The Turkish version of the CCTDI was also adapted in a second form to be suitable for primary school students. The CCTDI is composed of 75 items rated on a 6 point, forced-choice scale (1 = totally disagree, 2 = disagree, 3 = partially disagree, 4 = partially agree, 5 = agree, 6 = totally agree) and intends to measure 7 dimensions of critical thinking dispositions with 7 sub-scales. The scores for each of the seven subscales range from a possible minimum of 10, to a possible maximum of 60. Scores of 30 or below indicates a negative tendency toward that subscale; scores of 31–39 suggest ambivalence; scores of 40 or higher are evidence of a positive inclination, and scores between 50 and 60 indicate a strong positive tendency. The CCTDI total score is the sum of the seven subscale scores, and can range from 70 to 420; a total score of

280 or higher indicates a positive disposition toward critical thinking in samples (Facione, 2000; Iskifoglu, 2014). The translated Turkish version and the original English version of the CCTDI displayed positive psychometric properties, thus supporting the applicability of the CCTDI in a Turkish educational context, with alpha coefficients ranging from 0.81 and 0.90 for the sub-scales of the CCTDI in Turkish. Results also supported high content Sustainability 2023, 15, 15356 10 of 23 validity indicates of 0.81 and 0.97 (Iskifoglu, 2014) and high reliability scores for the sub-scales of the CCTDI; (1) Truth-seeking (12 items, α = 0.72), (2) Open mindedness (12 items, α = 0.73), (3) Analyticity (11 items, α = 0.72), (4) systematicity (11 items, α = 0.74), (5) Critical thinking self-confidence (9 items, α = 0.78), (6) Inquisitiveness (10 items, α = 0.80), and (7) Maturity of judgment (10 items, α = 0.75).

The second measurement tool utilized was the Mathematics achievement test, composed of 25 items specifically developed for this experiment. The development of the achievement test included several distinct processes, such as the preparation of the item pool from the related content domains, content validity check with the subject matter experts, pilot study, and reliability analysis. The initial item pool included 75 items. 28 items were then removed by two independent experts consistently, as they were considered either too difficult or too easy for the targeted audience. More importantly, every single item was checked against the related content domain, in terms of their relevance. The content validity indices (CVIs) for the rest of the 47 items ranged from 0.83 to 1, which symbolizes high acceptability for content validity (Cash et. al, 2016). Following the content validity check, items were first used to collect some initial data from a similar group of students (n = 200). The collected data were processed to make inferences for the reliability of items and the entire test in general.

Since there was only one correct answer for each multiple-choice item, the Kuder-Richardson 20 formula was utilized, as shown below.

$$KR20\ [k/k - 1] \times [1 - (\Sigma pj \times qj) / \sigma 2]$$

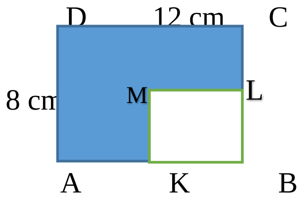
The KR20 was calculated using the Excel software version 2023, and applied to assess the degree of reliability for each item of the mathematics achievement test. When the results of analysis were interpreted, 20 items were found to be lower in terms of their reliability. Therefore, items with a KR20 score of 0.85 and above, were selected to establish the final form of the test. Finally, 25 items with high content validity indices ranging from 0.9 to 1, and with high KR20 scores ranging from 0.85 to 0.89, were chosen as the items to be used in the experiment, in assessment of the mathematics achievements of 5th grade primary school students. The detailed item content validity indices and KR20 values of each question in the mathematics achievement test, are displayed below in Table 1. The curriculum content domains and their correlated subject matters were considered the main source for the generated questions in the mathematics achievement test. The content domains and subject matters can be seen in Figure 3. The final version of the mathematics test included 25 items, corresponding with the subject matters covered during the 16 weeks throughout the experiment. Sample questions included in the test can be seen in Figure 6 below. Because the medium of instruction at the schools is Turkish, the question statements were translated to English, to be included in this paper.

Question Number	I-CVI[1]	KR20
Question 1	1	0.85
Question 2	0.9	0.89
Question 3	0.9	0.85
Question 4	0.9	0.88
Question 5	0.9	0.87
Question 6	1	0.85
Question 7	0.9	0.85
Question 8	1	0.85
Question 9	1	0.88
Question 10	0.9	0.85
Question 11	1	0.86
Question 12	1	0.85
Question 13	0.9	0.86
Question 14	1	0.85
Question 15	0.9	0.89
Question 16	0.9	0.85
Question 17	0.9	0.85
Question 18	0.9	0.88
Question 19	1	0.85
Question 20	0.9	0.86
Question 21	0.9	0.85
Question 22	0.9	0.86
Question 23	0.9	0.88
Question 24	0.9	0.85
Question 25	0.9	0.88

[1]I-CVI: Item Content Validity Index

Figure 5: Item Content Validity Indices and KR-20 scores of the Mathematics Achievement Test

(a)



A)20 B) 34 C) 72 D)82

In the figure, ABCD and KBLM are the midpoints of the sides on which the rectangle, K and L points are on.

|DC|=12 cm and |AD|= 8 cm, what is the area of the painted area is square centimeters?

(b)

Sevim , alanı 16 cm^2 olan bir kare çiziyor. İrem ise bu karenin kenar uzunluğundan 3 cm fazla kenar uzunluğuna sahip bir kare çiziyor.

Buna göre, İrem'in çizdiği karenin alanı, Sevim'im çizdiği karenin alanından kaç santimetrekare fazladır?

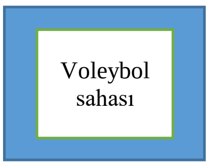
A)9 B)18 C)24 D)33

Sevim draws a square whose are is 16 cm^2. İrem draws a square with a side length of 3 cm more than the side length of this square.

Accordingly, by how many square centimeters is the area of the square drawn by İrem more than the area of the square drawn by Sevim?

(c)

Dikdörtgen şeklindeki zeminin bir kısmına aşağıdaki gibi dikdörtgen bir voleybol sahası çizilir. Voleybol sahasının zemin kenarlarına mesafesi eşit ve 4 metredir.



Voleybol sahasının uzun kenar uzunluğu 14 m, kısa kenar uzunluğu 9 m olduğuna göre zeminin alanı metrekare olarak ne kadardır?

A)126 B)262 C)234 D)374

A rectangular volleyball court is drawn on a portion of the rectangular floor as follows. The distance of the volleyball court to the edges of the ground are equal and 4 meters each.

If the long side lenght of the volleyball court is 14 m and the short side length is 9 m, what is the area of the floor in square meters?

Figure 5: Sample Questions of the Mathematics Achievement Test. (a): Sample Question about Measurements; (b) Sample Question about Areas; (c): Sampla Question Geometric Illustrations.

3.6 Data Collection Procedures

Prior to any data collection attempt, all the necessary permissions were collected from the Ministry of Education in North Cyprus (NC), from the parents of students and the students themselves, administrators, and applicator teachers (See Appendix ABGF). They were eventually informed about the aim of the research and informed about their rights in the study. They were also given the information that they could withdraw from the study at any time they desired without showing any reason for their withdrawal. After eliciting acceptance from all parties, the next procedure was to invite the teachers for an in-service training program in order to inform them in advance regarding the SP-STEAM education model. The training included STEAM procedures (explained in detail in a specially prepared booklet), materials, and technology and assessment procedures (See Appendix J). Following the completion of the teacher training program, data collection tools were administered to both defined control and experiment groups (pre-tests), in two distinct sessions. The first session included the demographic data collection and the administration of the CCTDI, and the second session included the administration of the mathematics achievement test. The former and the second sessions were administered on different days. In addition, participants were re-informed of their rights within the study, and informed on how they were going to take the tests and respond to each item in the inventory. After eliciting the initial data from the groups, the application of the treatment to the experiment groups followed as soon as the settings were ready. Meanwhile, the pre-existing procedures were maintained for the control groups. An SP-STEAM education model was administered to 5th-grade primary school students within a primary school setting in two separate experimental groups for 14 weeks, with an expectation of positive changes both in their mathematic achievements and their dispositions toward seven defined critical thinking facets. Following the completion of the treatment and the achievement test, the CCTDI was re-given to both the control and experiment groups, in order to check on any positive increments and/or improvements in their scores. The most important part of the data collection procedure was to maintain the consistency between and among the administration of the test and inventory, in order not to cause any bias with relation to the data collection.

3.7 Data Analysis Procedures

To conduct any analysis and to answer the first and the second research questions, a preliminary analysis was conducted to ensure the homogeneity of the data set distributions for both the control and experiment groups. The mean scores, standard deviations, lower and upper boundaries in the 95 percent of a confidence interval, minimum and maximum observations, skewness levels, kurtosis levels, standard errors for mean and deviation scores, and normality statistics were all conducted in order to make further decisions regarding the type of inferential statistics required to be considered for the each of the variables and data sets. The first and the second research questions are the ones that directly question the effect of the treatment model. In such group-wise comparisons, the most important facets to be focused upon are those at the entry-level of the groups in terms of the so-called endogenous variables. Therefore, as an initial analysis, the entry levels of the experiment and control groups were analysed and were compared to each other, in terms of the defined endogenous variables. This comparison was done by independent samples from a t-test, rather than the Mann–Whitney U test, because the Kolmogorov–Smirnov test and the Shapiro–Wilk tests showed no significant difference between the distributions of research data and the hypothetical normal distribution. Our expectation here was to elicit a non-significant difference, which is a sign that no covariate is needed for further group-wise analysis.

Once the prerequisite analyses were satisfied, the effect of the treatment model on the defined endogenous variables were tested via multiple-group split-plot ANOVA. This analysis was safely done with the SPSS 24 software. The logic behind selecting split-plot ANOVA was because the analysis involved two sets of scores within two independent groups for several endogenous variables (pre-test and post-test scores for two control and Sustainability 2023, two experiment groups). In such a complex design, where control over variables is hard to manage, a dedicated approach for analysis is essential (Cash, et. al, 2016), as is for this case.

3.8 Defining the California Critical Thinking Disposition Inventory-CCTDI

The 7 sub-scales of the CCTDI defining are following:

1. Truth-seeking: is to “seek the truth, courageous about asking questions, and honest and objective about pursuing inquiry, even if the findings do not support one’s interests or one’s preconceived opinions”
2. Open-Mindedness: is to be “open-minded and tolerant of divergent views with sensitivity to the possibility of one’s own bias.”
3. Analyticity: is to be “alert to potentially problematic situations, anticipating possible results or consequences, and prizing the application of reason and the use of evidence even if the problem at hand turns out to be challenging or difficult.”
4. Systematicity: is to be “organized, orderly, focused, and diligent inquiry in inquiry.”
5. CT Self-Confidence: refers to “the level of trust one places in one’s own reasoning processes.”

6. Inquisitiveness: is to have “intellectual curiosity by means of valuing being well informed and learning, even if the immediate payoff is not directly evident.”
7. Maturity of Judgment: is to make “reflective judgments based on cognitive maturity and epistemic development” (Facione & Facione, 1992, pp. 11-12).

3.9 Content Validity Estimation

This is a part of a dissertation study, which particularly focuses on assessing the reliability and validity of the achievement test consisting of mathematics and science as major concerns of STEM education.

There are three major parts. The first part includes content domains, definitions and objectives. Original questions have been created from those content domains. What is being tested is the relevance of those items to these content domains. The second part includes the content validity estimation scale that will be used to assess the relevance of each assessment question to the content that it is intended to belong to those domains. The third part is the achievement test as it will be administered to the targeted audience, who are 5th graders. The third part is given to you to think of the assessment tool so that it may help you to base your judgments in a holistic way.

As a comity member, you are being requested to assess the relevance of each item to the content from which the items were derived in terms of relevance to content, clarity, simplicity, and ambiguity on a four-point scale.Items were grouped according to the content domains in order to make your task easier.

The results obtained from each of the comity member will be analyzed and content validity indexes will be calculated for each item, for each scale, and for the whole assessment tool. Following the analysis of the results regarding content validity index, some items may need to be refined, rethought, or re-written.

One of the most important consequences of this part of the study is that it will provide an evidence regarding content and construct validity of the developed achievement test.

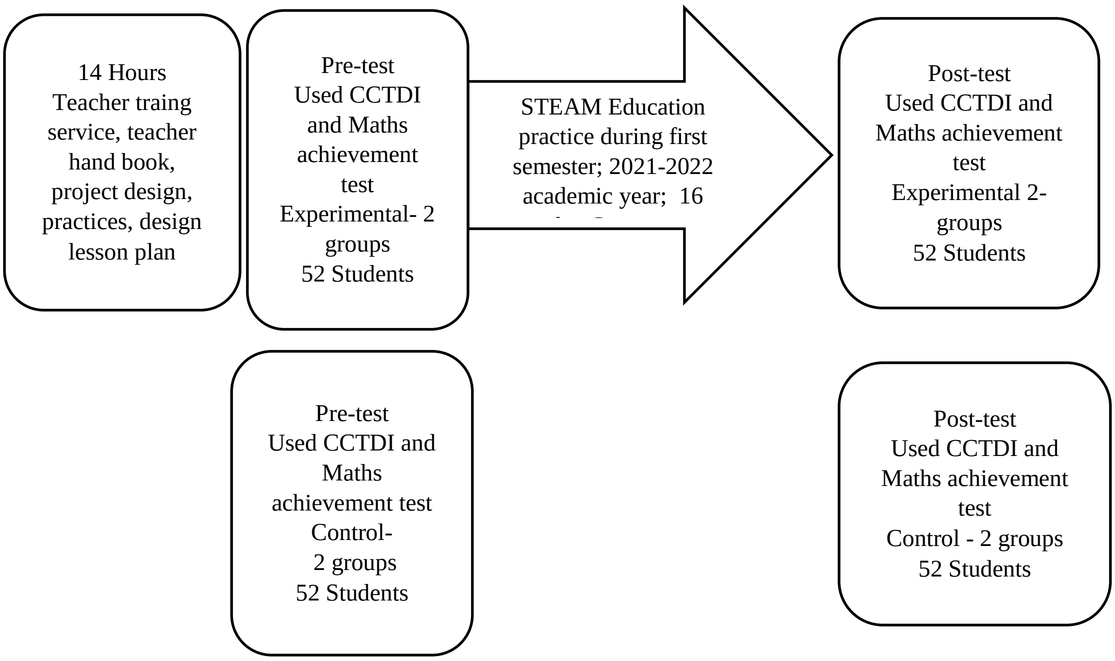


Figure 6: Proposed Research Model: Quasi-Experimental Study

Chapter 4

RESULTS

4.1 Presentation

This study which examined the effect of a progressive STEAM model on primary school students' critical thinking dispositions and academic achievements utilized a quasi-experimental research design and asked the following research questions respectively. In this section of the dissertation, the manuscript, thereby, reports the results derived from the experiment with sole objection.

The one-sample Kolmogorov–Smirnov test was used to determine if the data for the pre-test and post-test across experimental and control groups were distributed normally. The results gave non-significant sig (For 2-tailed bi-nominal distribution) values. For experimental groups, the alpha values showed to be 0.563 and 0.198 for each, and for control groups, the results also showed 0.110 and 0.174 for each variable. Based on the evidence that the results derived from, these data sets came from a normally distributed population, and parametric difference tests were preferred to test the hypothesis, because the research satisfied the preconditions of the F-test, suggested for experimental researches in social sciences (Cash, et. al, 2016).

4.2 Split-Plot ANOVA Results

4.2.1 Impact of SP-STEAM Model on Critical Thinking Dispositions Research Question 1

Will groups of 5^{th}-grade primary school students who are instructed by an SP-STEAM education model show statistically significant differences in comparison to similar groups of 5th-grade primary school students who are instructed by a traditional education model in terms of their critical thinking dispositions?

Results Regarding Research Question 1: Before using split-plot ANOVA to compare pre-post test results across experiment and control groups, one-way ANOVA was conducted to compare only the pre-test results between the experiment and control groups. The results showed no statistically significant difference between groups with Sig. scores ranging from 0.741 to 0.117, which meant that all groups were equal in terms of their CTDs.

Using split-plot ANOVA, cross-sectional analysis differences were tested to figure out if there were any statistically significant differences between groups across the pre-post-test administrations. The results of the analysis showed that the experiment groups where the SP-STEAM program was applied performed better (see Table 7 for means and standard deviations) across all sub-dimensions of the CCTDI, in comparison to the control groups where the progressive STEAM program was not applied (see Tables 7 and 8).

Table 7: Descriptive Statistics Regarding Seven Facets of Critical Thinking Dispositions across Pre-Post Test Design of Control and Experiment Groups

Variables	Design	Groups	Mean	Std. Deviation	n
Truth-seeking	Pre-Test	Experiment 1	24.1795	4.09035	26
		Experiment 2	22.3077	4.02760	26
		Control 1	20.8077	2.19124	26
		Control 2	24.2692	3.51634	26
		Total	22.8910	3.77422	104
	Post-Test	Experiment 1	33.7179	7.12285	26
		Experiment 2	32.9167	5.43778	26
		Control 1	20.5769	2.11987	26
		Control 2	23.6923	3.56392	26
		Total	27.7260	7.51916	104
Open-mindedness	Pre-Test	Experiment 1	22.1538	2.94879	26
		Experiment 2	25.5000	2.59615	26
		Control 1	24.9615	3.97473	26
		Control 2	22.6538	4.89034	26
		Total	23.8173	3.93334	104
	Post-Test	Experiment 1	36.3141	3.48148	26
		Experiment 2	30.9295	4.25785	26
		Control 1	23.3846	4.34582	26
		Control 2	21.6923	5.34991	26
		Total	28.0801	7.34182	104
Inquisitiveness	Pre-Test	Experiment 1	23.1154	2.86115	26
		Experiment 2	23.0000	2.28035	26
		Control 1	21.0385	2.40800	26
		Control 2	22.5000	3.40881	26
		Total	22.4135	2.85783	104
	Post-Test	Experiment 1	33.7308	4.37774	26
		Experiment 2	31.2692	5.43734	26
		Control 1	20.1923	2.65359	26
		Control 2	21.2692	4.38687	26
		Total	26.6154	7.35416	104
Systematicity	Pre-Test	Experiment 1	22.3077	3.51874	26
		Experiment 2	23.6154	2.57801	26
		Control 1	23.6923	3.72848	26
		Control 2	20.4231	2.53256	26
		Total	22.5096	3.36456	104
	Post-Test	Experiment 1	35.1748	4.30083	26
		Experiment 2	35.0699	4.99370	26
		Control 1	20.4615	3.30128	26
		Control 2	19.6923	2.60414	26
		Total	27.5997	8.48825	104
Analyticity	Pre-Test	Experiment 1	24.1795	4.09035	26
		Experiment 2	22.3077	4.02760	26
		Control 1	20.8077	2.19124	26
		Control 2	24.2692	3.51634	26
		Total	22.8910	3.77422	104
	Post-Test	Experiment 1	33.7179	7.12285	26
		Experiment 2	32.9167	5.43778	26
		Control 1	20.5769	2.11987	26
		Control 2	23.6923	3.56392	26
		Total	27.7260	7.51916	104
Maturity of Judgement	Pre-Test	Experiment 1	23.0385	5.86843	26
		Experiment 2	19.9615	3.91388	26
		Control 1	23.4231	3.63509	26
		Control 2	23.3846	3.71028	26
		Total	22.4519	4.55363	104
	Post-Test	Experiment 1	29.6538	7.00253	26
		Experiment 2	32.1154	6.59289	26
		Control 1	20.6154	5.26176	26
		Control 2	22.8462	3.84388	26
		Total	26.3077	7.43656	104

CT-Self Confidence	Pre-Test	Experiment 1	26.1154	3.79818	26
		Experiment 2	23.0000	3.40588	26
		Control 1	23.8462	2.52495	26
		Control 2	23.3077	2.42931	26
		Total	24.0673	3.28653	104
	Post-Test	Experiment 1	37.8205	6.17027	26
		Experiment 2	36.5812	6.97029	26
		Control 1	23.3462	3.74104	26
		Control 2	23.2308	2.61240	26
		Total	30.2447	8.66837	104
Overall Disposition	Pre-Test	Experiment 1	161.5641	10.28171	26
		Experiment 2	159.0385	10.86455	26
		Control 1	159.8077	8.37147	26
		Control 2	156.4231	6.57372	26
		Total	159.2083	9.23389	104
	Post-Test	Experiment 1	243.0554	14.79129	26
		Experiment 2	233.7770	14.92111	26
		Control 1	148.1538	6.86843	26
		Control 2	151.2308	7.69575	26
		Total	194.0542	46.17483	104

Specifically, the empirical evidence supported that experiment group 1 and experiment group 2 performed significantly better in post-test results in comparison to the post-test results of control group 1 and control group 2 in all sub-scales of the CCTDI (see Table7 for means and standard deviations; see Table 8 for post hoc Tukey F-test results and significance levels.

Table 8: Tukey F Post-hoc Results Regarding Mean Differences for Experiment and Control Groups across the Pre-Post Test Design

Variables	**Groups**		**df**	**F**	**Mean Difference**	**Std. Error**	**Sig.**
Truth seeking	Experiment 1	Experiment 2	3,100	32.541	1.3365	.92407	.474
		Control 1			8.2564	.92407	.000
		Control 2			4.9679	.92407	.000
	Experiment 2	Experiment 1			-1.3365	.92407	.474
		Control 1			6.9199	.92407	.000
		Control 2			3.6314	.92407	.001
	Control 1	Experiment 1			-8.2564	.92407	.000
		Experiment 2			-6.9199	.92407	.000
		Control 2			-3.2885	.92407	.003
	Control 2	Experiment 1			-4.9679	.92407	.000
		Experiment 2			-3.6314	.92407	.001
		Control 1			3.2885	.92407	.003
Open mindedness	Experiment 1	Experiment 2	3,100	90.636	1.0192	.99117	.733
		Control 1			5.0609*	.99117	.000
		Control 2			7.0609*	.99117	.000
	Experiment 2	Experiment 1			-1.0192	.99117	.733
		Control 1			4.0417*	.99117	.001
		Control 2			6.0417*	.99117	.000
	Control 1	Experiment 1			-5.0609*	.99117	.000
		Experiment 2			-4.0417*	.99117	.001
		Control 2			2.0000	.99117	.188
	Control 2	Experiment 1			-7.0609*	.99117	.000
		Experiment 2			-6.0417*	.99117	.000
		Control 1			-2.0000	.99117	.188
Inquisitiveness	Experiment 1	Experiment 2	3,100	42.618	1.2885	.75952	.331
		Control 1			7.8077*	.75952	.000
		Control 2			6.5385*	.75952	.000
	Experiment 2	Experiment 1			-1.2885	.75952	.331
		Control 1			6.5192*	.75952	.000
		Control 2			5.2500*	.75952	.000
	Control 1	Experiment 1			-7.8077*	.75952	.000
		Experiment 2			-6.5192*	.75952	.000
		Control 2			-1.2692	.75952	.344
	Control 2	Experiment 1			-6.5385*	.75952	.000
		Experiment 2			-5.2500*	.75952	.000
		Control 1			1.2692	.75952	.344
Systematicity	Experiment 1	Experiment 2	3,100	95.069	-.6014	.77982	.867
		Control 1			6.6643*	.77982	.000
		Control 2			8.6836*	.77982	.000
	Experiment 2	Experiment 1			.6014	.77982	.867
		Control 1			7.2657*	.77982	.000
		Control 2			9.2850*	.77982	.000
	Control 1	Experiment 1			-6.6643*	.77982	.000
		Experiment 2			-7.2657*	.77982	.000
		Control 2			2.0192	.77982	.053
	Control 2	Experiment 1			-8.6836*	.77982	.000
		Experiment 2			-9.2850*	.77982	.000
		Control 1			-2.0192	.77982	.053
Analyticity	Experiment 1	Experiment 2	3,100	32.541	1.3365	.92407	.474
		Control 1			8.2564*	.92407	.000
		Control 2			4.9679*	.92407	.000
	Experiment 2	Experiment 1			-1.3365	.92407	.474
		Control 1			6.9199*	.92407	.000
		Control 2			3.6314*	.92407	.001
	Control 1	Experiment 1			-8.2564*	.92407	.000
		Experiment 2			-6.9199*	.92407	.000
		Control 2			-3.2885*	.92407	.003
	Control 2	Experiment 1			-4.9679*	.92407	.000
		Experiment 2			-3.6314*	.92407	.001
		Control 1			3.2885*	.92407	.003
Maturity of Judgement	Experiment 1	Experiment 2	3,100	28.019	.3077	1.09623	.992
		Control 1			4.3269*	1.09623	.001

		Control 2			3.2308*	1.09623	.020
	Experiment 2	Experiment 1			-.3077	1.09623	.992
		Control 1			4.0192*	1.09623	.002
		Control 2			2.9231*	1.09623	.044
	Control 1	Experiment 1			-4.3269*	1.09623	.001
		Experiment 2			-4.0192*	1.09623	.002
		Control 2			-1.0962	1.09623	.750
	Control 2	Experiment 1			-3.2308*	1.09623	.020
		Experiment 2			-2.9231*	1.09623	.044
		Control 1			1.0962	1.09623	.750
CT-Self Confidence	Experiment 1	Experiment 2	3,100	43.891	2.1774	.87161	.066
		Control 1			8.3718*	.87161	.000
		Control 2			8.6987*	.87161	.000
	Experiment 2	Experiment 1			-2.1774	.87161	.066
		Control 1			6.1944*	.87161	.000
		Control 2			6.5214*	.87161	.000
	Control 1	Experiment 1			-8.3718*	.87161	.000
		Experiment 2			-6.1944*	.87161	.000
		Control 2			.3269	.87161	.982
	Control 2	Experiment 1			-8.6987*	.87161	.000
		Experiment 2			-6.5214*	.87161	.000
		Control 1			-.3269	.87161	.982
Overall Disposition	Experiment 1	Experiment 2	3,100	378.754	5.9020	2.27898	.053
		Control 1			48.3290*	2.27898	.000
		Control 2			48.4828*	2.27898	.000
	Experiment 2	Experiment 1			-5.9020	2.27898	.053
		Control 1			42.4270*	2.27898	.000
		Control 2			42.5808*	2.27898	.000
	Control 1	Experiment 1			-48.3290*	2.27898	.000
		Experiment 2			-42.4270*	2.27898	.000
		Control 2			.1538	2.27898	1.000
	Control 2	Experiment 1			-48.4828*	2.27898	.000
		Experiment 2			-42.5808*	2.27898	.000
		Control 1			-.1538	2.27898	1.000

When the F test results were interpreted with Tukey group-wise comparison result, it is vivid that the progressive STEM program made a considerable difference in the CTDs of 5th grade primary school students. Profile plots also showed the intercepts for better visual interpretation of the results since interpreting split-plot ANOVA results is complicated (see Figure 8 for profile plots for each facet of the CCTDI across pre-post-test design for experiment and control groups).

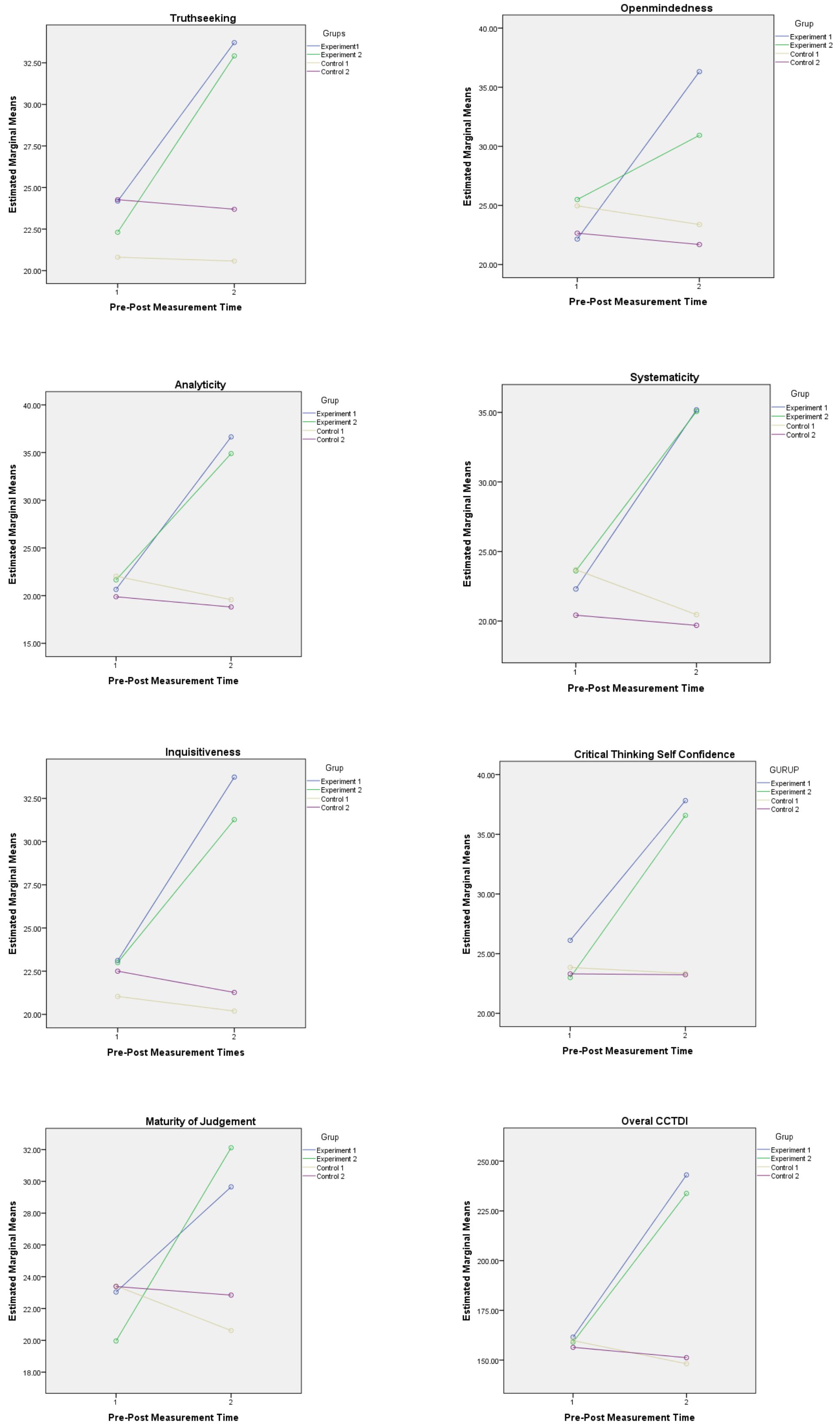


Figure 7: Profile Plots of Pre-Post Measurement Design across Groups Regarding CCTDI Subscales

4.2.2 Impact of SP-STEAM Model on Mathematics Achievement

Research Question 2: Will groups of 5th grade primary school students who are instructed by a progressive STEM education model show statistically significant differences in comparison to similar groups of 5th grade primary school students who are instructed by a traditional education model in terms of their mathematic achievements?

Results Regarding Research Question 2: Cross-sectional split-plot ANOVA result yielded that experiment group 1 and experiment group 2 displayed statistically significant differences ($F(3,100)40.581$, $p<0.001$) in comparison to control group 1 and control group 2 across pre-post test results, in terms of mathematics achievement (see Table 9 for descriptive data). No significant difference was observed in favor of control groups.

Table 9: Descriptive Statistics Regarding Mathematics Achievement Test across Pre-Post Test Design of Control and Experiment Groups

Variable	Design	Groups	Mean	Std. Deviation	n
Mathematic Achievement	Pre-Test	Experiment 1	71.1538	8.16182	26
		Experiment 2	74.6154	10.09189	26
		Control 1	72.1154	8.38726	26
		Control 2	71.7308	8.93782	26
		Total	72.4038	8.89477	104
	Post-Test	Experiment 1	89.2308	6.58670	26
		Experiment 2	81.1538	9.72704	26
		Control 1	71.7308	6.62455	26
		Control 2	74.6154	8.35740	26
		Total	79.1827	10.33682	104

Group-wise comparison was carried out, along with the Tukey post hoc test, in an effort to observe where significant differences existed between the groups. The test results yielded that significant differences only existed between the experiment groups and control groups in favor of the experiment groups, as shown in Table 10 below:

Table 10: Tukey F Post Hoc Results Regarding Mean Differences of Mathematics Achievement for Experiment and Control Groups across the Pre-Post-Test Design

Groups		df	F	Mean Difference	Std. Error	Sig.
Experiment 1	Experiment 2			0.3077	1.09623	0.992
	Control 1			4.3269	1.09623	0.001
	Control 2			3.2308	1.09623	0.020
	Experiment 1			-0.3077	1.09623	0.992
Experiment 2	Control 1			4.0192	1.09623	0.002
	Control 2	1.3	7.649	2.9231	1.09623	0.044
	Experiment 1			-4.3269	1.09623	0.001
Control 1	Experiment 2			-4.0192	1.09623	0.002
	Control 2			-1.0962	1.09623	0.750
	Experiment 1			-3.2308	1.09623	0.020
Control 2	Experiment 2			-2.9231	1.09623	0.044
	Control 1			1.0962	1.09623	0.750

Chapter 5

DISCUSSION AND CONCLUSION

Turkish Republic of Northern Cyprus (TRNC) is one of those countries that is pregnant for an upcoming drastically missing change in its educational system. Although it is known that STEAM education has some rigid principles in application, it also does have some flexible sides to be adapted to an existing educational system (Gomez and Albrecht, 2014). Besides the need for STEAM education, researchers question the way it is administered and practiced (Gomez and Albrecht, 2014; White, 2014). This is crucial because every society has its own dynamics, mimics, and cultural realms. For the time being, the optimum way of practice of STEAM education in TRNC and its effects on academic achievement and thinking quality of individuals were unknown. The extraneous factors that might possibly affect the process of administration of this approach are unknown and, there is no experimental results supporting the success of such administration. This is quite important because not every practice gives the same results and not every culture holds and responds to a new design the same way. For that very reason, it has long been an urgent need to design a STEAM education approach to be embedded in the educational context of the Turkish Republic of Northern Cyprus and to elicit empirical evidence regarding its effects on the targeted audiences' academic achievements and thinking qualities.

The vision of Northern Cyprus Education for 2023 strategic aims determined by Ministry of National Education, show the importance of appropriate application models of STEAM education (Vision 2023 Report Ministry of Education, 2019). If a country wants to have a say in scientific, economic, or technological fields, STEAM education must be considered in their education systems (Lacey & Wright, 2009). It is seen that studies on STEAM applications for primary school students are limited in Turkish Republic of Northern Cyprus. Based on this, STEAM application in the classroom at the primary school level were deemed necessary.

Based on a developed framework and as a part of this study, the current dissertation, which is supported by a quantitative empirical paradigm and aimed to figure out possible effects of a progressive STEAM education model on groups of 5th grade primary school students' CTDs and their academic achievements in the TRNC reached some intriguing results.

For the time being, the optimum way of practice of STEAM education in TRNC and its effects on academic achievement and thinking quality of primary school students were unknown. This quasi-experimental research aimed to test the impact of a progressive STEAM education design on 5th grade primary school students' CTDs and mathematic achievements in TRNC. When the results were evaluated, it is vivid that STEAM application had significant effects on students' CTDs and mathematical achievements (see Tables 7, 8, 9). As measured with CCTDI, both experimental groups scored significantly high in post-test results in comparison to pre-test results, and in comparison to post test results of control groups whereas control groups either remained same or displayed non-significant change in terms of the seven facets of CTDs. Similar effects were recorded for mathematic achievement too.

Students in experiment group 1 and 2 showed significantly higher progress in comparison to students in control group 1 and 2. The bulk of the literature had theoretically supported the possible effects of STEAM education on critical thinking and academic achievement (Yasin, Jauhariyah, Madiyo, Rahmawati, Farid, Irwandani, & Mardana, 2019; Yasin, Fakhri, Siswadi, Faelasofi, Safi'i, Supriadi, Syazali, & Wekke, 2020), however, no empirical evidence existed to prove this hypothesis until now, especially in TRNC. A recent research on enhancing mathematics critical thinking skills have revealed that STEM plays crucial roles for the development of CTDs (Syafril, Aini, Netriwati, Pahrudin, Yaumas, & Engkizar, 2020; Wendell, Connolly, Wright, Jarvin, Rogers, Barnett, and Marulcu, 2010). However, this study only mentioned the spirit of Mathematics. The current research deliberately tented to figure out the sole impact of STEAM on mathematics achievement.

One other important dimension that needs to be discussed is about the applicator teachers who were provided with in-service training regarding the correct application of STEAM in experiment groups. This opens up another discussion pint, which where applicators begin to be subjected to the sole contribution role regarding the effects of STEAM. As many research explained, any successful result would be obtained from applications where applicators were trained in advance (Aini, Syafril, Netriwati, Pahrudin, Rahayu, & Puspasari, 2019; Bybee, 2011; Carroll, 2014; Stein, Haynes, Redding, Ennis, Cecil, 2007). It is delightful that this research obeyed the suggestions of then related literature and the results are shockingly parallel to what the literature suggested. It is a well-known fact that it is a difficult task to graduate individuals who are keen to question, solve problems, be a world citizen, and be a good person, all at the same time (Means, Wang, Young, Peters & Lynch, 2016; Sahin, 2013; Sahin &

Top, 2015). The far aims of education determine the aims of the schools, lessons, and students. Educational policies are the determinants of the quality of education (Lacey & Wright, 2009). Education, on the other hand, within the era of globalization, is trying to achieve its goals. Various different strategies are being tested and used to create a culture of critical thinking (Bybee, 2010; National Academy of Engineering and National Research Council, 2014). However, very few of them succeed and very few of them are sustainable. The excitement that motivated this research is rooted in the call for research in the 2030 vision of North Cyprus, which was announced by the North Cyprus Ministry of Education (Armknecht, 2015; Thomasian, 2011). After longitudinal seminars and workshops, with the inclusion of many academicians, researchers, teachers, and educators, some critical decisions were made at the governmental level in North Cyprus. One of the decisions was to embed SP-STEAM applications to graduate individuals who can think critically and solve problems. This quasi-experimental research aimed to test the impact of a sustainable progressive STEAM education design on 5th-grade primary school students' CTDs and mathematic achievements. When the results were evaluated, it was vivid that the SP-STEAM application had significant effects upon students' CTDs and mathematic achievements. As measured with CCTDI, both the experimental groups scored significantly high in post-test results, in comparison to pre-test results, and in comparison to the post-test results of the control groups, whereas the control groups either remained the same or displayed non-significant changes in terms of the seven facets of CCTDI. Similar effects were recorded for mathematic achievements, too. When the experimental studies carried out in Turkey were evaluated, the results signified that if teaching-learning environments are redesigned according to the STEAM education model, then the students display increased performances in mathematics and in the use of their cognitive abilities (Ertmer and Newby, 2013; Greeno et al., 1996), which is a supportive finding for the current research. This experiment also presented that the control groups maintained the same performance, without any significant changes in their mathematic achievements and CTDs, even though the control groups followed the same curriculum content. Thus, the results of this experiment support the use of the SP-STEAM education model for mathematics achievement and for CTDs. Other countries, as well as Turkey, have seen researchers producing similar results in the application of the STEAM education. Significantly, numerous studies carried out across different countries appropriating the application of SP-STEAM education have all displayed improved academic achievements of the students in every respect, reporting positive increments in science, technology, and the mathematic achievements of primary school learners in comparison to non-STEAM education forms of teaching and learning (Brophy, et al., 2008).

For the last decade, there has been an increase in experimental researches in relation to the influences and impacts of the SP-STEAM oriented education, except for the period encompassing the pandemic. Consideration in this context reveals that the findings of many studies displayed parallelism with this study (Lim, Zhao, Tondeur, Chai, & Tsai, 2013; Tondeur, Cooper, & Newhouse, 2010), which emphasizes the validity and reliability of the current research. The bulk of the literature had theoretically supported the possible effects of STEAM education on critical thinking and academic achievement (Ehri, Dreyer, Flugman, & Gross, 2007; Torgesen, Wagner, Rashotte, Herron, & Lindamood, 2010); however, no empirical evidence existed to prove this hypothesis, especially in the context of North Cyprus. Recent research on enhancing mathematics critical thinking skills has revealed that STEAM plays a crucial role in the development of CTDs (Lowther, Inan, Ross, & Strahl, 2008; Silvernail, Pinkham, Wintle, Walker, & Bartlett, 2011). However, this study only mentioned the spirit of mathematics. The current research deliberately intended to figure out the sole impact of the SP-STEAM on mathematics achievement. One other important dimension that requires focus relates to the applicator teachers, who were provided with in-service training regarding the correct application of STEAM in experiment groups. This opens up another discussion point, which is where applicators begin to be subjected to the sole contribution role regarding the effects of the SP-STEAM. As many researches explained, any successful result would be obtained from applications where the applicators were well-trained (Morgan, Farkas, & Wu, 2009; Princiotta, Flanagan, & Germino Hausken, 2006). Obeying the suggestions of the related literature, it was found that the results were parallel to what has been proposed by the pioneers of the field (Duncan & Magnuson, 2011; Jordan, Kaplan, Ramineni, & Locuniak, 2009). What we have learned from the results of this research is that children can achieve well if they are provided with opportunities to use their potential. However, this requires background experience, and achieving goals in STEAM applications is very difficult without establishing a baseline with teachers who are well-trained for such applications.

STEAM, which forms an integrated model with the combination of different disciplines, enables students to look at the problems they face in a wide perspective. STEM also includes 21^{st} century skills that education systems aim to gain in students (Baran, Canbazoğlu Bilici, Mesutoğlu and Ocak, 2016). For this reason, using the activities prepared within the scope of STEAM education approach will enable students to develop the skills of science-technology-mathematics and engineering disciplines (MacFarlane, 2016) and increase their readiness (Thomasian, 2011). For countries to have a voice in the international arena, to compete and grow economically, STEM approach should be included in the education system (Çorlu, Capraro & Capraro, 2014; Lacey & Wrigh, 2009). Both in Turkey and TRNC, the Ministry of National Education published "Science, Engineering and Entrepreneurship applications," which says the subject field is added (Karakaya, Unal, Lawn and Yilmaz, 2018). The results of the current research can be considered invaluable in terms of underlining the positive impact of STEAM integration for upcoming years.

This experiment had some limitations that can be taken into considerations for further implications. Empirical studies, especially the experimental ones, are quite valuable because they can be repeated as they are in different settings with similar group of students. This experiment, though, considered mathematic achievement only. However, STEAM includes engineering, science, and technology applications as well. A further study may include these endogenous variables to test the complete effect of STEAM on other subject matters. In addition, conducting a further experiment with 4^{th}, 6^{th}, and 7^{th} grade students could be fruitful to see the effects of STEAM for different educational levels. Moreover, this research design can be turned into a true-experimental design with completely random sampling procedure with more participants enrolled in an experiment. In our research, to increase the validity of the results, two experimental groups were used against two control groups. A follow up study may include more than two experimental groups so that results would be more generalizable. Finally, factors associated with the application of STEAM, perceptions of students and applicators views on possible obstacles can be studied with a survey. The results of such studies have the potential to bring deeper insights into STEAM applications and its effects on various different exogenous variables. Specifically, the current research proposed that primary school students can achieve better when they are provided with better opportunities to use their potential. Additionally, experiments conducted with primary school students with an average age of 10 to 12 are rarely set upon in the literature (Duncan & Magnuson, 2011; Jordan, Kaplan, Ramineni, & Locuniak, 2009). Many studies have pointed out that STEAM education should be tested with primary school students to establish a STEAM culture at the middle school and high school levels. SP-STEAM, which forms an integrated model with a combination of different disciplines, enables students to look at the problems they face from a wider perspective. STEAM also includes the 21st-century skills that education systems aim to transfer to students (Bricker & Bell, 2008). For this reason, using the activities prepared within the scope of the STEAM education approach will enable students to develop the skills of the science-technology-mathematics and engineering disciplines (Ebenezer, Kaya, & Ebenezer, 2011) and increase their readiness (Figliano, 2007). For countries to have a voice in the international arena to compete and grow economically, the STEAM approach should be included in education systems (Bybee, 2010; Sanders, 2009). In North Cyprus, the Ministry of National Education published "Science, Engineering and Entrepreneurship applications", which says the subject field is added (Kuenzi, 2008).

The results of the current research can be considered invaluable in terms of underlining the positive impact of STEAM integration and the importance of in-service teacher training. This experiment had some limitations that can be taken into consideration for further implications. Empirical studies, especially experimental ones, are valuable due to the possibilities of their repetition in different settings with similar groups of students. This experiment took mathematic achievements into consideration only. However, SP-STEAM includes engineering, science, and technology applications as well. A further study may include these endogenous variables to test the complete effect of SP-STEAM on other subject matters. In addition, conducting further experiments with 4th-, 6th-, and 7th-grade students could be fruitful to see the effects of SP-STEAM against different educational levels. Moreover, this research design can be turned into a true experimental design with a completely random sampling procedure and more participants enrolled in the experiment. In our research, to increase the validity of the results, two experimental groups were used against two control groups. A follow-up study may include more than two experimental groups, making the results more generalizable. Finally, factors associated with the application of SP-STEAM, perceptions of students, and the applicators' views on possible obstacles can also be studied with a survey. The results of such studies have the potential to bring deeper insights into STEAM applications and their effects on various exogenous variables.

Suggestions for Further Studies: This experiment had some limitations that can be taken into consideration for further implications. Empirical studies, especially experimental ones, are valuable due to the possibilities of their repetition in different settings with similar groups of students. This experiment took mathematic achievements into consideration only. However, SP-STEAM includes engineering, science, and technology applications as well. A further study may include these endogenous variables to test the complete effect of SP-STEAM on other subject matters. In addition, conducting further experiments with 4th-, 6th-, and 7th-grade students could be fruitful to see the effects of SP-STEAM against different educational levels. Moreover, this research design can be turned into a true experimental design with a completely random sampling procedure and more participants enrolled in the experiment. In our research, to increase the validity of the results, two experimental groups were used against two control groups. A follow-up study may include more than two experimental groups, making the results more generalizable. Finally, factors associated with the application of SP-STEAM, perceptions of students, and the applicators' views on possible obstacles can also be studied with a survey. The results of such studies have the potential to bring deeper insights into STEAM applications and their effects on various exogenous variables.

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APPENDICES

Appendix A: Ligability Paper of the Ethics Committee

Doğu Akdeniz Üniversitesi
"Erdem, Bilgi, Gelişim"

Eastern Mediterranean University
"Virtue, Knowledge, Advancement"

99628, Gazimağusa, KUZEY KIBRIS /
Famagusta, NORTH CYPRUS,
via Mersin 10, TURKEY
bayek@emu.edu.tr

Bilimsel Araştırma ve Yayın Etiği Kurulu (BAYEK) / Board of Scientific Research and Publication Ethics

Reference No: ETK00-2022-0012 06.01.2022

Subject: Your application for ethical approval.

Re: Hasan Küçük

Faculty of Education

EMU's Scientific Research and Publication Ethics Board (BAYEK) has approved the decision of the Ethics Board of Education (24.12.2022 tarih ve 2021/107) granting Hasan Küçük from the Faculty of Education to pursue his PhD thesis titled **"The Impact of a Progressive STEM Education Model on the Critical Thinking Dispositions and Academic Achievements of 5. Grade Primary School Students"** supervised by Assoc. Prof. Dr Canan Zeki and Assoc. Prof. Dr. Hamit Caner.

Best Regards,

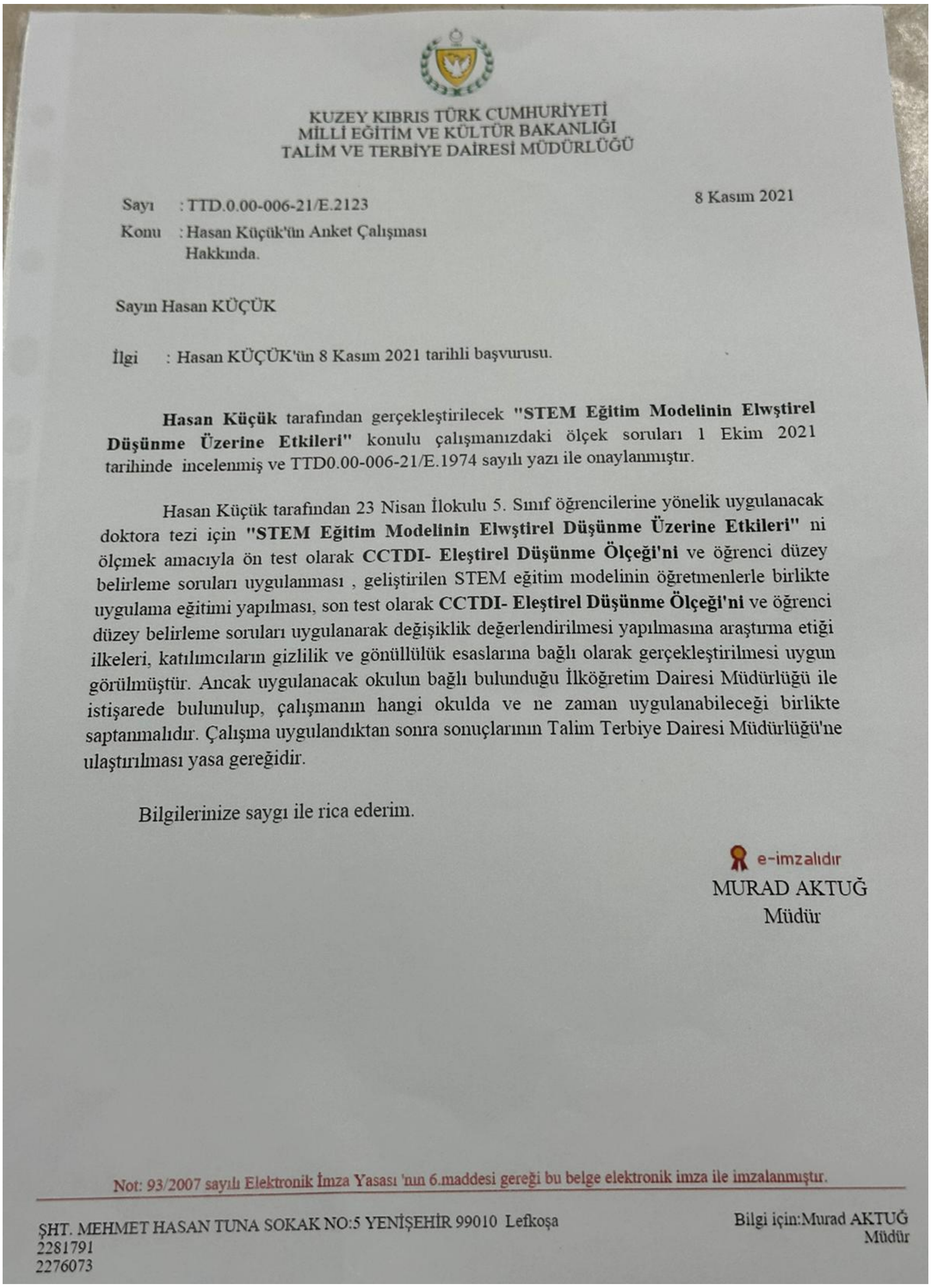
Prof. Dr. Yücel Vural

Chair, Board of Scientific Research and Publication Ethics - EMU

YV/ek.

www.emu.edu.tr

Appendix B: Permission of the Minister of Education



KUZEY KIBRIS TÜRK CUMHURİYETİ
MİLLİ EĞİTİM VE KÜLTÜR BAKANLIĞI
TALİM VE TERBİYE DAİRESİ MÜDÜRLÜĞÜ

Sayı : TTD.0.00-006-21/E.2123 8 Kasım 2021

Konu : Hasan Küçük'ün Anket Çalışması Hakkında.

Sayın Hasan KÜÇÜK

İlgi : Hasan KÜÇÜK'ün 8 Kasım 2021 tarihli başvurusu.

Hasan Küçük tarafından gerçekleştirilecek **"STEM Eğitim Modelinin Elwştirel Düşünme Üzerine Etkileri"** konulu çalışmanızdaki ölçek soruları 1 Ekim 2021 tarihinde incelenmiş ve TTD0.00-006-21/E.1974 sayılı yazı ile onaylanmıştır.

Hasan Küçük tarafından 23 Nisan İlokulu 5. Sınıf öğrencilerine yönelik uygulanacak doktora tezi için **"STEM Eğitim Modelinin Elwştirel Düşünme Üzerine Etkileri"** ni ölçmek amacıyla ön test olarak **CCTDI- Eleştirel Düşünme Ölçeği'ni** ve öğrenci düzey belirleme soruları uygulanması , geliştirilen STEM eğitim modelinin öğretmenlerle birlikte uygulama eğitimi yapılması, son test olarak **CCTDI- Eleştirel Düşünme Ölçeği'ni** ve öğrenci düzey belirleme soruları uygulanarak değişiklik değerlendirilmesi yapılmasına araştırma etiği ilkeleri, katılımcıların gizlilik ve gönüllülük esaslarına bağlı olarak gerçekleştirilmesi uygun görülmüştür. Ancak uygulanacak okulun bağlı bulunduğu İlköğretim Dairesi Müdürlüğü ile istişarede bulunulup, çalışmanın hangi okulda ve ne zaman uygulanabileceği birlikte saptanmalıdır. Çalışma uygulandıktan sonra sonuçlarının Talim Terbiye Dairesi Müdürlüğü'ne ulaştırılması yasa gereğidir.

Bilgilerinize saygı ile rica ederim.

e-imzalıdır
MURAD AKTUĞ
Müdür

Not: 93/2007 sayılı Elektronik İmza Yasası 'nın 6.maddesi gereği bu belge elektronik imza ile imzalanmıştır.

ŞHT. MEHMET HASAN TUNA SOKAK NO:5 YENİŞEHİR 99010 Lefkoşa
2281791
2276073

Bilgi için:Murad AKTUĞ
Müdür

Appendix C: Content Validity Estimation Study

<u>Information for Comity Members:</u>

- This is a part of a dissertation study, which particularly focuses on assessing the reliability and validity of the achievement test consisting of mathematics and science as major concerns of STEM education.

- There are three major parts. The first part includes content domains, definitions and objectives (see PART A). Original questions have been created from those content domains. What is being tested is the relevance of those items to these content domains. The second part (see PART B) includes the content validity estimation scale that will be used to assess the relevance of each assessment question to the content that it is intended to belong to those domains. The third part (see PART C) is the achievement test as it will be administered to the targeted audience, who are 4^{th} graders. The third part is given to you to think of the assessment tool so that it may help you to base your judgments in a holistic way.

- As a comity member, you are being requested to assess the relevance of each item to the content from which the items were derived in terms of *relevance to content*, *clarity*, *simplicity*, and *ambiguity* on a four-point scale (see PART B). Items were grouped according to the content domains in order to make your task easier.

- The results obtained from each of the comity member will be analyzed and content validity indexes will be calculated for each item, for each scale, and for the whole assessment tool.

- Following the analysis of the results regarding content validity index, some items may need to be refined, rethought, or re-written.

- One of the most important consequences of this part of the study is that it will provide an evidence regarding content and construct validity of the developed achievement test.

- For any further explanation, clarification, or concern please contact Hasan Küçük by telephone at 05338296626 or by e-mail at hasankucuk38@gmail.com . His graduate supervisor, Assoc. Prof. Dr. Canan Zeki, may be contacted by e-mail at canan.zeki@emu.edu.tr

Appendix D: Question Evaluation Scale Item Informed Consent Form

Soru Değerlendirme Ölçek Madde Bilgilendirilmiş Onam Formu

Değerli katılımcılar,

Doğu Akdeniz Üniversitesi Eğitim Bilimleri Fakültesi Doktora tez çalışması olan bu araştırmanın temel amacı; KKTC devlet ve özel okulları 4.sınıf öğrencilerinde "STEM eğitiminin eleştirel düşünme beceri düzeyleri ve akademik başarılarına etkilerini araştırmak" için hazırlanmıştır.

Bu çalışma, 2021-2022 Eğitim ve öğretim yılı dönem başı giriş ve dönem sonu çıkış davranışlarının matematik ve fen bilgisi derslerinde öğrencilerin bilgi düzeylerinin belirlenmesi amacıyla hazırlanıştır. Yapacağınız ölçek madde değerlendirmesi sonunda maddelerin kapsam geçerliliği değerlendirilecek ve maddelerin son şekli verilecektir.

Değerlendirme sonunda elde edilecek maddeler doktora tezi kapsamında ve yalnızca bilimsel amaçlı kullanılacaktır. Çalışmanın ilkokul 4. Sınıflarda yürütülebilmesi için Eğitim ve Kültür Bakanlığı'ndan gerekli uygulama izinleri alınmıştır.

Değerlendirmenizi Eğitim ve Kültür Bakanığı tarafından 2019 yılında hazırlanan ilköğretim 4.sınıf matematik ve fen bilgisi dersleri müfredatları ve her öğrencinin sahip olması gereken 21.yy becerileri temel alınarak değerlendirmeniz gerekmektedir.

Çalışma hakkında daha detaylı bilgi edinmek isterseniz benimle veya tez danışmanlarım ile iletişime geçebilirsiniz. İletişim bilgileri:

Doç. Dr. Canan Zeki
Doktora Tez Danışmanı
Doğu Akdeniz Üniversitesi
canan.perkan@emu.edu.tr
Tel: 0392 630 1001

Doç. Dr. Hamit Caner
Doktora Eş Tez Danışmanı
Doğu Akdeniz Üniversitesi
hamit.caner@emu.edu.tr
Tel: 0392 630 1415

Hasan Küçük
Doktora Öğrencisi
Doğu Akdeniz Üniversitesi
hasankucuk38@gmail.com
Mobile Tel.: 0533 8296626

Çalışma süresince ve sonrasında isminiz gizli tutulacak. İstediğiniz zaman çalışmadan gönüllü olarak geri çekilebilirsiniz. Ölçek madde değerlendirme bilgilendirilmiş onam formunu gönüllü olarak okudum ve anladım.

Değerlendirme Hakem İmzası: **Tarih:**

Appendix E: STEM Education Model Curriculum

21.yy Becerileri Evrensel okuryazarlık temelinde: Diğital okuryazarlık becerisi,Yaratıcı düşünme becerisi ,Etkili iletişim Becerisi,Yüksek verimlilik becerisi,Ruhsal değerler, teknoloji okuryazarlığı, trafik ve güvelik becerileri, mühendislik becerileri (Bu beceriler, OECD(2020) ve Dünya Bankası (2020) rekabet edebilirlik raporunda tanımlanmış becerilerdir).
Fen ve Teknoloji Öğretim Programı'nda, Sarmal Programlama Yaklaşımı kullanılmıştır. Bu yaklaşıma göre: Fen ve Teknoloji dersi için belirlenen dört öğrenme alanının (Fiziksel Olaylar, Madde ve Özellikleri, Canlılar ve Hayat, Uzay ve Evren) Fen-Teknoloji-Mühendislik-Çevre İlişkisi öğrenim çıktıları çercevesinde 6 başlıkta toplanmıştır. Sosyo-bilimsel konuları muhendislik Mantığı ile değerlendirmek. Bilimin doğası. Bilim ve teknoloji ilişkisi. Bilimin toplumsal katkısı. Sürdürülebilir kalkınma bilinci.ç Fen ve kariyer bilini. 21 yy. Becerileri : Evrensel okuryazarlık çercevesinde 5 beceri ile tanımlanmıştır. Diğital okuryazarlık, Yaratıcı düşünme, Etkili iletişim, Yüksek verimlilik, Ruhsal değerler Duyuşsal Davranışlar (tutum ve değerler): Öğrenilen kazanımı 4 başlıkta davranışa yansıtması olarak kabul edilmekedir. Tutum, motivasyon, değerler, sorumluluk 4'üncü sınıftan 8'inci sınıf öğretim çıktıları birbirleriyle sarmal bir yapıda örüntülenmiştir. "Fen ve Teknoloji Dersi", ilkokul 4 ve 5'inci sınıflarını ile ortaokulların 6, 7 ve 8'inci sınıflarını kapsamaktadır. Belirlenen öğrenme alanlarına, Fen-Teknoloji-Mühendislik-Çevre İlişkisi, 21 yy. Beceriler ve Duyuşsal Davranışlar her sınıf bazında sarmal bir yaklaşımla yazılan öğrenme çıktıları örüntüsünün şekilsel görüntüsü aşağıdaki gibidir:

STEM EĞİTİM MODELİ

ÇATI KAZANIMLAR

GENEL HAYAT PROBLEM İlişkilendirme

- 21 yy BECERİLER
- MÜFREDATTAKİ TEMEL DERS KAZANIMLARI

Kazanım tablosu ekde yer almaktadır. Teknoloji-mühendislikte yer alan kazanımlarımız bu proje kapsamında referansları ile birlikte STEM Uygulamaları kazanımları ek bölümündedir. Örnek etkinlik ile değerlendirme sorularına STEM kazanımlarından entegre edilmiştir.

Akademik takvimde yer alan derslerin ünite ve öğrenme alanı sarmal yapı içerisindedir(KKTC Milli Eğitim ve Kültür Bakanlığı Talim ve Terbiye Dairesi Öğretim Programı-2019).
STEM Eğitim modeli kapsamında ilgili ayda yapılacak STEM etkinlik projeleri; çatı kazanımları –yani fen bilgisi, matematik, teknoloji, mühendislik disiplinkerindeki kazanımları içermektedir.

STEM Etkinlikleri: Genel hayat problem tanımı- Yani etkinliğin yaşamamızdaki önemini anlatır.

Proje Başlığı-Problemin proje çercevesinde işleneceğini anlatır.

Çatı kazanımları-STEM temel beceriler ile 4.sınıf okul müfredatındaki kazanımlarım günlük hayat problem cümlesindeki kazanıların ilişkilendirilmesini anlatır.

Bu modelleme ile STEM eğitimi etkinlikleri hazırlanırken ;
— Eğitim programının içeriğini canlandırıcı bir öğrenme ortamı sağlaması,
— Öğrencilerin yeni buluşlar keşfetmesini, olaylar arasındaki ilişkiyi daha iyi anlamaları olanağını sağlamak,
— Yeni ürün ortaya koyarak, ekosisteme katkı sağlamak ve toplumsal sorumlu konunda farkındalık artırmak,

— İşbirliği ve bağımsız çalışma yoluyla öğrencilerin özgüven ve öz yeterliliğini geliştirmesi,
— Öğrencileri esneklik ve güven içinde düşünmeye teşvik etmek,
— 21. Yüzyıl becerilerini kazandırmaya olanak sağlamak,
— Karşılaştıkları sorunlara daha kısa çözümler üretmeyi sağlamak,
— Öğrenme motivasyonunu artırmak,
— Tasarım odaklı düşünme ve yenilikçi olmayı sağlamaktır.

21.Yüzyıl Becerileri

Araştırma kapsamında uluslararası OECD (2020) raporu temel alınarak iş dünyası ile okul ilişkisi temel alınarak "İletişim adaptasyon ve inovasyon yetenekleri" ana iskeleti oluşturmaktadır. Bu bağlamda mezun olan her öğrencinin ortalama olarak sahip olması gereken temel beceriler ve Harward Universitesinden Dr. Tony Wagner tarafından iş dünyası ile yapılan liderlik konusunda araştırma sonuçlarına göre her öğrencinin ihtiyaç duyacağı mesleki 7 temel becerileri aşağıdaki başlıklar altında sınıflandırılır temel kabul edilmiştir.
1.Öğrenme ve yenilenme becerileri;Yaratıcılık ve Yenilenme, Eleştirel Düşünme ve Problem Çözme ,İletişim ve İşbirliği
2.Bilgi, medya ve teknoloji becerileri;Bilgi Okuryazarlığı, Medya Okuryazarlığı, Bilgi ve İletişim Teknolojileri (ICT) Okur-Yazarlığı
3.Yaşama ve meslek becerileri;Esneklik ve Uyum, Girişimcilik ve Öz-Yönelim, Sosyal ve Kültürlerarası Beceriler, Üretkenlik ve Sorumluluk, Liderlik ve Sorumluluk olarak tanımlanmıştır.

4.Sınıf Matematik Dersi Öğrenme Çıktıları

Programın amacı öğrencilere yaşamlarında ve sonraki eğitim aşamalarında karşılaşacakları durumları anlamlandırmada, kendilerini ifade etmede ve problemleri çözmede matematiksel dil, yöntem ve süreçlerini kullanma bağlamında beceri kazandırmaktır.

Program Temel Çıktıları

1. Matematiğe karşı olumlu tutum geliştirebilme. 2. Matematiğin önemini takdir edebilme. 3. Zihinden hesaplamalar yapabilme. 4. Temel işlemleri akıcı olarak yapabilme. 5. Problem çözebilme. 6. Problem kurabilme (yazabilme). 7. Çalışmalarda; araç gereçlerden doğru bir biçimde yararlanabilme. 8. Matematiksel dili etkili biçimde kullanabilme 9. Matematikteki temsil biçimlerini etkili biçimde kullanabilme 10. Şekil, yer ve mekâna ilişkin durumlar hakkında muhakeme yapabilme 11. Geometrik şekiller ve kavramlar arasındaki ilişkileri kavrayabilme. 12. Basit/Temel cebirsel işlemleri akıcı olarak yapabilme. 13. Matematiksel modeller kurabilme. 14. Matematiksel düşünme yollarınıkullanabilme ve çıkarımda bulunabilme. 15. Matematiksel çalışmalarda grupla çalışabilme
4.Sınıf Fen Dersi Öğrenme Çıktılar Program Çıktıları Fen ve Teknoloji Öğretim Programı'nın önemi ve amaçlarına uygun olarak belirlenen ve öğrencilerin programı tamamladığında sahip olması beklenen en geneldeki nitelik ve yeterlilikleri şunlardır: 1. Fen ve teknolojinin doğasını, ikisi arasındaki ilişkiyi, bunların toplum ve çevreyle etkileşimlerini anlar. 2. Bilimsel keşif ve teknolojik gelişmiyle insanların bilgi ve anlayışlarında meydana gelen değişimleri kavrar.

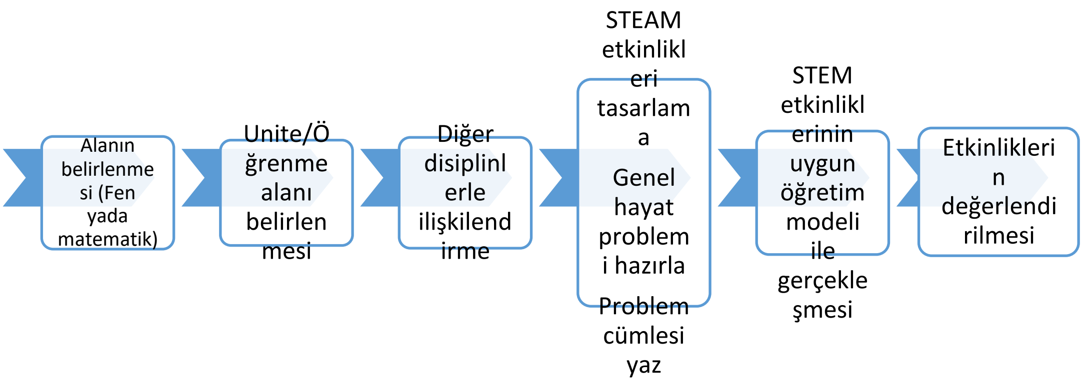
3. Günlük yaşamda ve deneysel ortamda fen ve teknoloji ile ilgili araç-gereçleri etkin ve bilinçli kullanır.
4. Fen ve teknoloji ile ilgili olayları,bilimsel süreççerçevesinde açıklar.
5. İşbirliğini, verimliliği, girişimciliği içeren anlayışlarla fen ve teknoloji alanında, yeni ve yaratıcı fikirleri uygun tasarımlarla hayata geçirir.
6. Karşılaştığı fen ve teknoloji problemlerine, bilimsel düşünme ve bilgiye ulaşma yolları kullanarak yeni çözümler önerir.
7. Fen ve Teknoloji ile ilgili olgu, olay veyeniliklere yönelik eleştirel, sorumlu tutum ve beceriler geliştirir.
8. Sağlıklı yaşam bilinciyle hareket eder.
9. Sürdürülebilir bir gelişim için çevreye, biyolojik çeşitliğe ve doğal estetiğe duyarlı anlayışlarla neden-sonuç ilişkilerini bilimsel verilerle tartışır.
10. Fen ve teknoloji alanında kendi yaş grubuna uygun her türlü yayını takip eder.
11. Kültürel ve doğal mirasın yaşatılmasında sosyal sorumluluk alarak, proje ve çalışmalara gönüllü olarak katılır.
12. Dünya, Uzay ve Evren arasındaki ilişkiyi içselleştirip, bu ilişkiyi bilimsel veriler çerçevesinde tartışır.

Teknoloji Okuryazarlık Kazanımları: Fen ve matematik bilgilerinin kullanılması sonucunda teknolojik gelişmeler ortaya çıkmaktadır. Araştırmacılar fen ve matematik bilgisi doğrultusunda teknolojik problemler çözümlenmektedir. Teknoloji entegrasyonu, fen ve matematik bilgilerin kullanılarak teknolojik problemleri çözmek değil aynı zamanda teknoloji ile birlikte toplumun her alanda ihtiyacını da karşılamaktır. Bu sebepten dolayı fen ve matematik entegrasyonu, teknoloji entegrasyonu ile birlikte düşünülmeli, ayrı düşünülmemelidir. Sonuç olarak, teknoloji, toplumun her alanında sosyal, kültürel, ekonomik birçok alanda fen, matematik ve teknoloji entegrasyonu sonucunda karşılaşılan problemlerin çözümlenmesi ya da araçların kullanılması olarak görülmektedir (Yıldırım ve Altun, 2015)

Mühendilik Tasarım Kazanımları: Mühendislik Tasarımı altında bir mühendislik probleminin tanımlanması ve sınırlarının belirlenmesi, çözüm oluşturulması ve çözümün optimize edilmesi basamaklarını içeren mühendislerin problemleri nasıl çözdüğüne; ikincisi ise Mühendislik, teknoloji, bilim ve toplum arasındaki bağlantılar altında öğrencilerin bilim, mühendislik ve teknolojinin birbirine nasıl bağlı olduğunu ve bunların toplum ve çevre üzerindeki etkilerini anlamaları üzerine odaklanmıştır (NRC, 2012). Mühendislerin problem çözme yaklaşımı olan mühendislik tasarım süreci birinci boyutta yer alan bilim ve mühendislik için ortak olan, "problemi belirleme, model geliştirme ve uygulama, sorgulama, verileri analiz etme ve yorumlama, matematik ve hesaplamalı düşünmeyi kullanma ve çözüme karar verme gibi birçok farklı gibi uygulamaları içerir (NRC, 2012, s. 204).

STEAM Öğretim Modeli Ders Etkinlik Süreçi 6- Aşamalı

Yıldırım, B. (2018). Teoriden pratiğe STEAM eğitimi. İstanbul. Nobel Bilimsel Eserler



Bu araştırma STEAM ayrı bir ders olarak değil, 5 sınıf öğretmeni tarafından matematik ve fen bilgisi derslerini verdiği için bir öğretmenin vereceği kabul edilmektedir.

Bu araştırmada, öğretmen yeterliliğini, mesleki gelişim eğilimlerini, okul fiziki altyapıyı ortalama denk olarak kabul edilmektedir.

KAZANIM MERKEZLİ STEM UYGULAMA İZLENCESİ ETKİNLİK-ÜNİTE İLİŞKİSİ							
AY DÖNEM	**DERS**	**ÜNİTE**	**ÖĞRENME ALANI**	**KAZANIM SAYISI**	**DERS AĞIRLIK %**	**ANAHTAR KAVRAM (Öğrenciyi günlük hayatta karşılaşabileceği problem durumlarda öğrenma alanı ile akıl yürütme sürecinde tutumlar)**	**STEAM ETKİNLİK** **(Etkinlik tasarlanırken;öğrnme çıktları-kazanımlar ile 21.yy temel becerileri ilişkilendirilip çatı kazanımlar hazırlanmıştır.** **Ders anlatım süreci 5E öğretim modeli düşünülerek tasarlanmıştır.5E öğretim uygulama aşamaları sayfa .... yer almaktadır.)**
EYLÜL-EKİM I.DÖNEM	MATEMATİK	Doğal Sayılar Temel Geometri	Sayılar Geometrik Kavramlar	6 4	% 8	Sayı, İlişkilendirme İşlem üzerinden problem çözer, açıklamalar yapar, sonuçlar çıkarır, alternatifine karar verir ve bilgileri yeni duruma uyarlar.	**Genel Hayat Problemi:** Problem cümlesi: Plansız yapılanma ve ekonomik koşullardan ötürü köylerden merkezi şehirlere göç nüfusunun artması sonucu çevre kirliliğinin önüne geçilemiyor.Sonuç olarak artan çevre kirliliği ve sağlık sorunları arıyor. Proje Adı: Denizler Hayvalar Hepimizin! Çatı Kazanımlar etkinlik detaylandırmasında Proje uygulama : Örnek çalışma https://www.youtube.com/watch?v=ocU--lS1aOM
	FEN BİLGİSİ	VÜCÜDUM	Canlılar ve Hayat Duyu Organları İskele, Kas ve Hareket Solunum Dolaşım	23	% 17	Canlı Yaşamı, Organizma ve sindirim sistemini düşünerek problem çözer, açıklamalar yapar, sonuçlar çıkarır, alternatifine karar verir ve bilgileri yeni duruma uyarlar.	
EKİM - KASIM	MATEMATİK	Dört İşlem Açılar	Toplama-Çıkarma-Çarpma İşlemi Açı çeşitleri ve özellikleri	15 8	% 19	Açıların mantığı ve dört işlemlerle problem çözer, açıklamalar yapar,	**Genel Hayat Problemi:** Hangi meslek alanını seçersek seçelim mutlaka iş alanında veya günlük yaşamda iş araç ve makinelerinin çalışma prensipleri hakkında filir sahibi olmalıyız. Fotokopi makinesinden finç makinesine kadar temel çalışma prensinini bilmeliyiz.

						sonuçlar çıkarır, alternatifine karar verir ve bilgileri yeni duruma uyarlar.	Problem Cümlesi: Her işte ortak temel mantığa sahip olmalıyız. Proje adı: Temel iş makinleri Çatı Kazanımlar etkinlik detaylandırmasında Proje uygulama Örnek Çalışma linki https://youtu.be/NBNXc4FGcD4
	FEN BİLGİSİ	KUVVET ve HAREKET	Canlılar ve Hayat İtme ve Çekme Kuvvetin Etkileri Hareket	13	% 9	Hareket Kuvvet Etki	**Genel Hayat Problemi:** Hayvaları sevmek bizlere huzur verir. Birçok kişi evinde veya bahçesinde çeşitli hayvan türü yetiştirmektedir. Yoğun iş temposu ve beklenmedik zamanlarda hayvanlarımızın temel beslenmesi için sıkıntı yaşayan birçok aile vardır.Bunun için yaratıcı araştırmalar yapılmaktadır. Problem Cümlesi: Her hayvanın beslenme saatinde yiyeceğini bekler Çatı Kazanımlar etkinlik detaylandırmasında Proje uygulama Örnek Çalışma linki https://youtu.be/RGIW5e2QbVI (Beyin fırtınası çalışması) https://youtu.be/VdbQKr0SLZs
KASIM-ARALIK	MATEMATİK	Dört İşlem Açılar	Bölme İşlemi Açı ve işlemler	6 4	% 8	Bölme işlemleri ile açı çeşitlerini problem üzerinde ilişkilendirir. Çevrrsindeki madde özellikleri ile ilgili problem çözer, açıklamalar yapar, sonuçlar çıkarır, alternatifine karar verir ve bilgileri yeni duruma uyarlar.	
	FEN BİLGİSİ	MADDE ve ÖZELLİKLERİ	Madde ve Özellikleri Maddenin Değişimi Madenin Halleri Saf Maddeler ve Karışım	26	% 19		
ARALIK-OCAK	MATEMATİK	Kesirler Çokgenler Çokgenler	Kesir Çeşitleri Kesir işlemler Üçgen ve Özellikleri Dikdörtgen ve Özelikleri	12 4 4	% 17	Çokgen ve kesir problemleri çevresel durumlarda ilişkilendirip problem çözer, açıklamalar yapar, sonuçlar çıkarır, alternatifine karar verir ve bilgileri yeni duruma uyarlar.	**Genel Hayat Problemi:** Çevre ve insan sağlığı açısından alternatif enerji tartışmaları artarak devam etmektedir. Ülke eğitim sistemleri özellikle enerji tasarrufu için etkin çalışma yaparak bilinçli öğrencilerin yetişmesi sonucu enerji alanındaki tasarruf geek ekonomik gerekse kalkınma açısından çok önemlidir. Problem Cümlesi: Alternatif enerji ve enerji tasarrufu otak sorunumuzdur. Çatı Kazanımlar etkinlik detaylandırmasında Proje uygulama Örnek Çalışma linki https://www.youtube.com/channel/UCrTpskdV-Jg3SvdY_rf2DLg
	FEN BİLGİSİ	IŞIK ve SES	Fiziksel Olaylar Işık Kaynakları Aydınlatma Teknolojisi Işığın Görmedeki Rolü Işık Kirliliği Ses Kaynakları Ses Teknolojisi	23	% 17	Fiziksel olayların değişiminde ışık ve ses kaynakları üzerinden değerlendirme yapar, problem çözer, açıklamalar yapar, sonuçlar çıkarır,	

			Sesin İşitmedeki Rolü Ses Kirliliği			alternatifine karar verir ve bilgileri yeni duruma uyarlar.	
ŞUBAT – MART II.DÖNEM	MATEMATİK	Kesirler Çokgenler	Kesir ve Problemler Kare-Alan-Çevre Özellikleri ve İşlemler	7 12	%16	Canlıların yaşam alanları hakkında geometrik şekillerle yorumlayıp çeşitli işleleri insan ve çevre ilişkisi üzerinden değerlendirir problem çözer, açıklamalar yapar, sonuçlar çıkarır, alternatifine karar verir ve bilgileri yeni duruma uyarlar.	**Genel Hayat Problemi**: Dünya genelinde son 20 yılda depremlerin artması sonucu bina inşaat zemin etüd ve deprem yasasınında 2015 yılında ülkemizde günçelenmiştir. Toprak alan yapı özelliklerine inşat yapı çeşitleride değişmeye başlamıştır. Problem Cümlesi: Verimli toprak alanları yerine inşaat yapılmamalıdır. Proje Adı: Toprak Kaybı Proje örnek uygulama linki https://www.youtube.com/watch?v=RQXa5iJVxzk&feature=youtu.be
	FEN BİLGİSİ	CANLILAR DÜNYASI	Canlılar ve Hayat Canlı ve Cansız Varlıklar Canlıların Özellikleri Canlıların Yaşam Alanları İnsan ve Çevre İlişkisi	16	%12		
MART-NİSAN	MATEMATİK	Kesirler Ölçüm	Kesir ve Dört İşlemler Zaman,Ölçme,Tartma	7 6	%11	Fiziksel olaylardaki değişiklikleri, elektrik ihtiyaç ve gerekliliği grafiksel ilişkilendirip problem çözer, açıklamalar yapar, sonuçlar çıkarır, alternatifine karar verir ve bilgileri yeni duruma uyarlar.	
	FEN BİLGİSİ	YAŞAMIMIZ-DAKİ ELEKTRİK	Fiziksel Olaylar Elektrikle Tanışalım Elektrik Kaynakları Basit Bir Elektrik Devresi Elektriğin Bilinçli ve Güvenli Kullanımı	20	%14		**Genel Hayat Problemi**: İş dünyasında teknolojinin rtkin kullanıldığı çağdayız. Otomasyon kullanımı sonucu üretim ve iş gücündeki maliyet azalması ve birim saatte artan üretim miktarı ile rekabet edebilirlilik artmıştır. Bu bağlamda da hemen hemen her iş sektörü depolama sistemini geliştirmiştir. Bu bağlamda bir noktadan bir noktaya güvenli bir şekilde mal taşıma amacıyle sanayi sektöründe hidrolik sistemler yygınlaşmıştır. Problem cümlesi: A noktasından B noktasına taşınacak malı hidrolik sistemle kontrollü taşıma ihtiyaçıız vardır. Proje Adı: Hidrolik sistemle tanışma Proje örnek uygulama linki https://www.youtube.com/watch?v=mAevnWO9c5E&feature=youtu.be
NİSAN-MAYIS	MATEMATİK	Ölçüm ve Grafik Geometrik Cisimler	Sıvıları Ölçme Sütün Grafiği Olasılık Simetri ve Örüntü	18 7	%21	Dünyamızdaki hareketlerin nedenlerinden elde edilen verilerin ölçümler üzerinden grafiklendirilmesi, neden-sonuç ilişkisi kurma ve bunu belli temel	
	FEN BİLGİSİ	DÜNYA, AY ve GÜNEŞ	Fiziksel Olaylar Yıldızımız Güneş Dünyamızı Tanıyalım Dünyamızın Hareketi	17	%12		

			Ayın Özellikleri ve Hareketi			mantık çercevesinde problem çözer, açıklamalar yapar, sonuçlar çıkarır, alternatifine karar verir ve bilgileri yeni duruma uyarlar.	
		Öğrenme Alanı Kazanımlar	Matematik	120	%100		
			Fen Bilgisi	138	%100		

Etkinlik Çatı Kazanımlarının Detaylandırılması

"Eğitimde STEAM Temelli Etkinlik Tasarım Yarışması" (Muğla İl Millî Eğitim Müdürlüğü) kapsamında öğretmenlerin hazırladıkları örnek etkinlikleri https://mugla.meb.gov.tr/ ve https://muglaarge.meb.gov.tr/projeler/stem/index.php adreslerinden ulaşabilir. Kaynak göstermek gerekmektedir.

Eylül-Ekim: Denizler Hayvanlar Hepimizin Projesi Çatı Kazanımları
Fen Bilgisi
1.Sağlıklı bir yaşam için temizliğin gerekliliğini açıklar.
2.Bitki ve hayvanların yaşaması için gerekli olan şartları karşılaştırır.
3.Tüketilen maddelerin geri dönüşümüne katkıda bulunur.

Matematik
1.Standart olmayan farklı ölçme birimlerini kullanarak bir uzunluğu ölçer.
2.Uzunlukları standart araçlar kullanarak metre ve santimetre cinsinden ölçer.

Teknoloji
1.Kişisel öğrenme hedeflerini başarmak için teknolojiden yararlanan stratejiler geliştirir.
2.Sahip oldukları bilgiler ile gelişen teknolojileri anlar.
3. Gerçek dünya sorunlarını ve problemlerini aktif olarak keşfederek fikir ve teoriler geliştirerek,
4. Cevaplar ve çözümler üzerinde durarak bilgi havuzu oluşturur.
5.Fikir üretmek, teorileri test etmek, yenilikçi eserler yaratmak veya gerçek problemleri çözmek
için bilinçli bir şekilde tasarım sürecini kullanır.
6. Döngüsel bir tasarım sürecinin bir parçası olarak prototipler geliştirir.

Mühendislik
1.Bir proje için ihtiyaç duyulan temel süreçleri açıklar.
2.Tüm hesaplama ve ölçümlerde uygun birimleri kullanır.
3.Fiziksel ve mekanik sistem problemleriyle ilgili tasarım konseptleri uygular.

Ekim-Aralık: Temel İş Makineleri

Fen Bilgisi:

1.Hareket eden varlıkları gözlemler ve hareket özelliklerini ifade eder.
2.İtme ve çekmenin birer kuvvet olduğunu deneyerek keşfeder.
3.İtme ve çekme kuvvetlerinin hareket eden ve duran cisimler üzerindeki etkilerini gözlemleyerek kuvveti tanımlar.
4.Günlük yaşamda hareketli cisimlerin sebep olabileceği tehlikeleri tartışır.

Matematik:

1.Küp, kare prizma, dikdörtgen prizma, üçgen prizma, silindir, koni ve küre modellerinin yüzlerini, köşelerini, ayrıtlarını belirtir.
2.Küp, kare prizma ve dikdörtgen prizmanın birbirleriyle benzer ve farklı yönlerini açıklar.
3.Cetvel kullanarak kare, dikdörtgen ve üçgeni çizer; kare ve dikdörtgenin köşegenlerini belirler.
4.Bir metre, yarım metre, 10 cm ve 5 cm için standart olmayan ölçme araçları tanımlar ve bunları kullanarak ölçme yapar.
5. Cetvel kullanarak uzunluğu verilen bir doğru

Teknoloji:

1.Bir proje için ihtiyaç duyulan temel süreçleri açıklar.
2. Sahip olduğu bilgiler ile gelişen teknolojileri anlar.
3.Teknolojinin neden ve nasıl ilerlediğini inceler.
4. Fikir üretmek, teorileri test etmek, yenilikçi eserler yaratmak veya gerçek problemleri çözmek için bilinçli bir şekilde tasarım sürecini yönetir.

Mühendislik:

1.Doğaç yapma süreç döngüsünü kullanır.
2. Mühendislik tasarımı metodolojilerini uygular.
3. Özel problemlere mühendislik yaklaşımları uygular.

Kasım-Aralık:Her hayvanın beslenme saatinde yiyeceğini bekler

Fen Bilgisi:

1. Hareket eden varlıkları gözlemler ve hareket özelliklerini ifade eder .
2.Hareket eden varlıkları gözlemler ve hareket özelliklerini ifade eder .
3.Beş duyu organını kullanarak maddeyi niteleyen temel özellikleri açıklar .
4.Beş duyu organını kullanarak maddeyi niteleyen temel özellikleri açıklar.

Matematik:

1.Cetvel kullanarak kare, dikdörtgen ve üçgeni çizer; kare ve dikdörtgenin köşegenlerini belirler
2.Şekil modelleri kullanarak kaplama yapar, yaptığı kaplama örüntüsünü noktalı ya da kareli kâğıt üzerine çizer. 2*40
3.Şekillerin birden fazla simetri doğrusu olduğunu şekli katlayarak belirler.
4.Bir parçası verilen simetrik şekli dikey ya da yatay simetri doğrusuna göre tamamlar.

Teknoloji Tasarım:

1.Tasarım sürecinin bir problem tanımlama ve çözüm önerme süreci olduğunu söyler.
2.Günlük hayatta karşılaşılan bir sorun, ihtiyaç veya gerçekleştirebileceği hayalini "tasarım problemi" şeklinde ifade eder.
3.Belirlediği probleme yönelik geliştirdiği çözüm önerisini paylaşır.
4.Tasarım sürecinin araştırma basamaklarını söyler.
5.Ergonomik bir ürün tasarlar.
6.Tasarladığı eşyayı ergonomi kriterlerine göre değerlendirir.
7.Bir ürünün temel işlevinin gerektirdiği mekanik özellikleri sınıflandırır.
8.Tasarım planı hazırlar.
9.Tasarımın modelini veya proto tipini oluşturur.
10.Tasarladığı ürünü değerlendirme sonuçlarına göre yeniden yapılandırır.

Mühendislik
1.İnovasyon (yenilik) kavramını açıklar.
2.İnsan hayatını kolaylaştıracak inovatif bir fikir geliştirir.
3.Geliştirdiği inovatif fikri değerlendirir.
4.Geri bildirimler doğrultusunda inovatif fikrini yeniden geliştirir.
5.Mühendislik ve tasarım ilişkisini ifade eder.
(Mühendislik alanları ile tasarım boyutu arasındaki ilişki üzerinde durulur.)
6.Çevresindeki ürünleri mühendislik ve tasarım kavramları açısından ilişkilendirir.
7.Mühendislik tasarım sürecindeki sınırlılıkları değerlendirir.
8.Mühendislik tasarım sürecini kullanarak bir ürün tasarlar ve sunar .
(İhtiyaç veya problem içeren bir senaryo verilmesi ve bu senaryodaki ihtiyaç yahut problemi, iş birliği ile belirli sınırlılıkları dikkate alarak çözen bir ürün geliştirilmesi üzerinde durulur)

Aralık-Ocak: Alternatif Enerji ve Enerji Tasarrufu

Fen Bilgisi:
1.Uygun aydınlatma hakkında araştırma yapar.
2.Çalışan bir elektrik devresi kurar.
3.Aydınlatma araçlarının tasarruflu kullanımının aile ve ülke ekonomisi bakımından önemini tartışır.
4.Kaynakların kullanımında tasarruflu davranmaya özen gösterir.
5.Gelecekte kullanılabilecek aydınlatma araçlarına yönelik tasarım yapar.

Matematik:
1.Paralarla ilgili problemleri çözer.
2.Doğal sayılarla toplama, çıkarma, çarpma ve bölme işlemi gerektiren problemleri çözer.
3.Sütun grafiği, tablo veya diğer grafiklerle gösterilen bilgileri kullanarak günlük hayatla
ilgili problemleri çözer.

Teknoloji:
1. Bilim kitlerini kullanarak istenen algoritmayı oluşturur.
2.Algoritmaya ilişkin modülleri bilir ve bu modülleri kullanır.

Mühendislik:
1.Problem için muhtemel çözümler üretir, bunları karşılaştırarak ölçütler kapsamında uygun olanı seçer.
2.Öğrenci uygun set ve materyalleri kullanarak prototip tasarımı planlar.
3.Bu planlama tasarımı paralelinde tasarımını gerçekleştirir.
4.Tasarımındaki mühendislik sürecini açıklar.

Şubat-Mart: Toprak Kaybı Projesi Çatı Kazanımları

Fen Bilgisi

1.Yaşadığı çevreyi tanır.
2. Doğal ve yapay çevre arasındaki farkları açıklar.
3. Yapay bir çevre tasarlar.
4. Doğal çevrenin canlılar için öneminin farkına varır.
5.Doğal çevreyi korumak için araştırma yaparak çözümler önerir.

Matematik

1.Şekillerin alanını standart olmayan uygun malzeme ile kaplar ve ölçer.
2.Bir alanı, standart olmayan alan ölçme birimleriyle tahmin eder ve birimleri sayarak tahminini kontrol eder.

Mühendislik

1.Ürün Oluşturma ve Girişimcilik Mühendislik tasarım sürecinde aşağıdaki aşamaların izlenmesi beklenmektedir:
2.Günlük hayattan veya endüstriyel ihtiyaçlardan yola çıkarak bir problem tanımlar.
– Problemin malzeme, zaman ve maliyet kriterleri kapsamında ele alınması beklenir.
- Problemin günlük hayatta kullanılan veya karşılaşılan araç, nesne veya sistemleri geliştirmeye yönelik olması istenir.
3. Problem için muhtemel çözümler üretir ve bunları karşılaştırarak kriterler kapsamında uygun olanı seçer.
4.Ürünü tasarlar ve sunar.

Teknoloji

1.Çevresindeki herhangi bir yerin konumu ile ilgili çıkarımlarda bulunur.
2.Yaşadığı çevredeki doğal ve beşerî unsurları ayırt eder.
3.Ekleme, çıkarma, içten ve dıştan kuvvet uygulama yoluyla farklı malzemeleri kullanarak üç boyutlu çalışma yapar.

Nisan-Mayıs: Hidrolik sistemle tanışma

Fen Bilgisi:

1.Hareket eden varlıkları gözlemler ve hareket özelliklerini ifade eder.
2.İtme ve çekmenin birer kuvvet olduğunu deneyerek keşfeder.
3.İtme ve çekme kuvvetlerinin hareket eden ve duran cisimler üzerindeki etkilerini gözlemleyerek kuvveti tanımlar.
4.Günlük yaşamda hareketli cisimlerin sebep olabileceği tehlikeleri tartışır.
5.Çevresindeki maddeleri, hallerine göre sınıflandırır.

Matematik:

1. Nesnelerin çevrelerini belirler.
2.Şekillerin alanını standart olmayan uygun malzeme ile kaplar ve ölçer.
3.Cetvel kullanarak uzunluğu verilen bir doğru parçasını çizer.

Mühendislik:

1.Öğrenci temel bilim, teknoloji ve mühendislik disiplinlerinin ve bu alanlardaki kariyer fırsatlarının ayırdına varır.
2. Öğrenci bir mühendislik projesinin içerdiği süreçleri tespit eder. Planlama, prototip oluşturma, tasarım, yürütme, kalite kontrol ve raporlama gibi aşamaları açıklar.
3. Öğrenci proje çalışmasında kendisini farklı rollerdeki bir takım üyesi olarak varsayarak o rolün gerektirdiği çalışmaları başarıyla tamamlar.
4. Öğrenci proje çalışması sırasında kullandığı malzemelere ve çevreye özen göstererek çalışır. Tehlikeli malzemeleri güvenli bir şekilde kullanarak ve atıkları uygun şekilde yok etmeyi başarır.
5. Öğrenci görsel, yazılı ve sözlü iletişim yöntemlerini kullanarak fikirlerini ve bulgularını profesyonel hedef kitleye açık ve tutarlı olarak ifade eder ve tartışır.

Teknoloji:

1.Öğrenci, algoritmik problem çözerken, çözümlerin tasarımında basit adımlar kullanabilir. (örn:, problemin açıklaması ve keşfi, örnek durumların incelemesi, tasarı, uygulama, sınama ve değerlendirme)
2.Öğrenci, aynı problemi çözebilecek diğer algoritmaları değerlendirebilir.
3.Öğrenci, problemlerin ifadelerinde, yapılarında ve verilerinde görsel sunumlar kullanır
4.Öğrenci, modelleme ve simülasyon kullanarak ne tür problemlerin çözülebileceğini değerlendirir.
5.Öğrenci, bir problemi alt problemlerine ayırmak için soyutlama yapar.
6.Öğrenci, hesaplamalı düşünmenin disiplinler arası uygulamalarından örnekler gösterir.
7.Öğrenci, problemin karmaşıklığını düzenlemek için soyutlamanın değerini tartışır.
8.Öğrenci, problemleri çözümü kolay, çözümü zorlu veya hesaplayarak çözülemez olarak sınıflandırır.
9.Öğrenci, algoritmaları verimliliğine, doğruluğuna ve anlaşılabilirliğine göre değerlendir.

*Kaynak: BAUSTEM, Bütünleşik Öğretmenlik Projesi (Integrated Teaching Project) Hedef-Kazanım
Yazma Rehberi ve listesi

Appendix F: Permission of the Parents

18 Yaş Altı – EBEVEYN ARAŞTIRMA GÖNÜLLÜ KATILIM FORMU

Bu çalışma, STEAM Eğitim Modelinin Öğrencilerin Akademik Başarısı ve Eleştirel Düşünme Eğilimlerine olan Etkisi başlıklı bir araştırma çalışması olup öğrencilerin akademik ve eleştirel düşünme eğilimlerine olumlu katkı sağlama amacını taşımaktadır. Çalışma, doktora öğrencisi Hasan Küçük tarafından yürütülmekte ve sonuçları ile bir doktora tezi ortaya konacaktır ve KKTC eğitim alanına ve gelişimine ışık tutulacaktır.

● Bu çalışmaya katılımınız gönüllülük esasına dayanmaktadır.

● Bu çalışma kapsamında herhangi bir ses kaydı veya görüntü alınmayacaktır.

● Çalışmanın amacı doğrultusunda, deney grubundaki öğrencilerin 21. Yüzyıl becerilerini geliştirmek amaçlı, STEAM Eğitim Modeli kapsamında 5 E Öğretim Yöntemine uygun olarak öğrencilerle Fen ve Matematik alanlarında 14 hafta boyunca sınıf içi STEAM etkinlikleri ve sınıf dışı STEAM proje çalışmaları yürütülecektir. Bu uygulamalar STEAM Eğitim Modelinin ve 5 E Öğretim Yönteminin ilkeleri doğrultusunda gerçekleştirilecektir.

● Çalışmanın amacı doğrultusunda, sadece anket soruları ile çocuğunuzdan veriler toplanacaktır.

● Bu uygulama çocuğunuzun diğer derslerdeki performansını veya notunu olumsuz yönde etkilemeyecektir.

● Çocuğunuz bu araştırma sırasında psikolojik, sosyal veya akademik olarak mağdur olmayacaktır.

● Çocuğunuzun İsminizi yazmasına ya da kimliğini açığa çıkaracak bir bilgi vermesine gerek yoktur.

● Araştırma kapsamında toplanan veriler, sadece bilimsel amaçlar doğrultusunda kullanılacak, araştırmanın amacı dışında ya da bir başka araştırmada kullanılmayacak ve gerekmesi halinde, sizin (yazılı) izniniz olmadan başkalarıyla paylaşılmayacaktır.

● İstemeniz halinde çocuğunuzdan toplanan verileri inceleme hakkınız bulunmaktadır.

● Çocuğunuzdan toplanan veriler kripto dosya kilidi yöntemi ile korunacak ve araştırma bitiminde arşivlenecek veya imha edilecektir.

● Veri toplama sürecinde/süreçlerinde size rahatsızlık verebilecek herhangi bir soru/talep olmayacaktır. Yine de çocuğunuzun araştırma sürecindeki katılımı sırasında herhangi bir sebepten rahatsızlık hissederseniz çocuğunuz çalışmadan istediğiniz zamanda ayrılabilecektir. Çalışmadan ayrılmanız durumunda çocuğunuzdan toplanan veriler çalışmadan çıkarılacak ve imha edilecektir.

Gönüllü katılım formunu okumak ve değerlendirmek üzere ayırdığınız zaman için teşekkür ederim. Çalışma hakkındaki sorularınızı Doğu Akdeniz Üniversitesi Eğitim Bilimleri Bölümünden Doç. Dr. Canan Zeki'ye (canan.zeki@emu.edu.tr) yöneltebilirsiniz.

Araştırmacı Adı: Hasan Küçük Cep Tel 05338296626

Bu çalışmaya çocuğumun katılmasına tamamen kendi rızamla, istediğim takdirde çocuğumu çalışmadan ayrılabileceğimi bilerek verdiğim bilgilerin bilimsel amaçlarla kullanılmasını Kabul ediyorum.

(Lütfen bu formu doldurup imzaladıktan sonra veri toplayan kişiye veriniz.)

Katılımcı Ad ve Soyadı:

İmza:

Tarih:

Appendix G: Permission of the Teachers

ÖĞRETMEN - ARAŞTIRMA GÖNÜLLÜ KATILIM FORMU

Bu çalışma, *STEAM Eğitim Modelinin Öğrencilerin Akademik Başarısı ve Eleştirel Düşünme Eğilimlerine olan Etkisi* başlıklı bir araştırma çalışması olup öğrencilerin akademik ve eleştirel düşünme eğilimlerine olumlu katkı sağlama amacını taşımaktadır. Çalışma, doktora öğrencisi Hasan Küçük tarafından yürütülmekte ve sonuçları ile bir doktora tezi ortaya konacaktır ve KKTC eğitim alanına ve gelişimine ışık tutulacaktır.

- Bu çalışmaya katılımınız gönüllülük esasına dayanmaktadır.
- Çalışmanın amacı doğrultusunda, size STEAM eğitim modeli hakkında 16 saatlik bir hizmet içi eğitim verilecektir. Bu eğitim STEAM uzmanı tarafından yüz yüze ve çevrim içi olmak üzere 2 platformda gerçekleştirilecektir. Bu eğitimin amacı STEAM eğitiminin önemini vurgulayıp, STEAM Eğitimi yaklaşımının okul ve sınıf ortamında nasıl Uygulanabileceğini basit ve adım adım sizlere aktarmak olacaktır. Haftalık ve günlük ders planlarınızı 5-E Modeline göre anahtar sorular baz alınarak nasıl hazırlayacağınız, nasıl uygulayacağınız ve nasıl ölçüp değerlendireceğiniz hakkında eğitim verilecektir.
- Bu çalışma kapsamında isminiz gizli tutulacak ve kesinlikle çalışma içerisinde yer almayacaktır.
- Araştırma kapsamında toplanan veriler, sadece bilimsel amaçlar doğrultusunda

Kullanılacak, araştırmanın amacı dışında ya da bir başka araştırmada kullanılmayacak ve gerekmesi halinde, sizin (yazılı) izniniz olmadan başkalarıyla paylaşılmayacaktır.

- İstemeniz halinde sizden toplanan verileri inceleme hakkınız bulunmaktadır.
- Uygulama ve veri toplama sürecinde/süreçlerinde size rahatsızlık verebilecek herhangi bir soru/talep olmayacaktır. Yine de katılımınız sırasında herhangi bir

Sebepten rahatsızlık hissederseniz çalışmadan istediğiniz zamanda ayrılabileceksiniz. Çalışmadan ayrılmanız durumunda sizden toplanan veriler çalışmadan çıkarılacak ve imha edilecektir.

Gönüllü katılım formunu okumak ve değerlendirmek üzere ayırdığınız zaman için teşekkür ederim. Çalışma hakkındaki sorularınızı Doğu Akdeniz Üniversitesi Eğitim Bilimleri Bölümünden Doç. Dr. Canan Zeki'ye (canan.zeki@emu.edu.tr) yöneltebilirsiniz.

Araştırmacı Adı: Hasan Küçük Cep Tel 05338296626

Bu çalışmaya tamamen kendi rızamla, istediğim takdirde çalışmadan ayrılabileceğimi bilerek verdiğim bilgilerin bilimsel amaçlarla kullanılmasını kabul ediyorum.
(Lütfen bu formu doldurup imzaladıktan sonra veri toplayan kişiye veriniz.)

Katılımcı Ad ve Soyadı: İmza:
Tarih:

Appendix H: Permission Of CCTDI by Californian Academy USA

October 01, 2020

Hasan Kucuk (PhD Candidate)

Insight Assessment A division of California Academic Press
Measuring Critical Thinking Worldwide

Eastern Mediterranean University

Faculty of Education

Dear Hasan Kucuk,

I am happy to confirm that you have permission from the authors and copyright holders, Dr. Noreen Facione, Dr. Peter Facione, Gokhan Iskifoglu and from the publisher, The California Academic Press / Insight Assessment, to use the CCTDIT-Turkish to collect data up to #200# (two hundred) participants. You are officially authorized to use the CCTDIT-Turkish by California Academic Press / Insight Assessment. This is to certify that copyright has been checked with all the relevant parties. As is our custom when acknowledging our international researchers and contributors, we request them to send data file to the corresponding translator for initial analyses of the data since we do not reveal scoring procedures.

Yours,

James Morante, Ph.D

Managing Director

The California Academic Press / Insight Assessment

INSIGHT ASSESSMENT

217 LA CRUZ AVE.
PHONE (650) 697-5628

MILLBRAE, CA 94030
www.insightassessment.com
FAX (650) 692-0141

Appendix I: Californian Critical Thinking Disposion Invontory (CCTDI)

Bu çalışma doktora tezi olarak, "STEAM eğitiminin 5.sınıf öğrencilerin eleştirel düşünme düzeylerine etkilerini araştırmak" için hazırlanmıştır.

Öğrenci Tanılayıcı Form

LÜTFEN, Uygun olan ☐ kutu içini karalayınız. Okul:.......................
Sınıf:.............Öğrenci no: ....

Cinsiyet Kız ☐ Erkek ☐ Okul .... İlkokulu

- Düzenli olarak sosyal faaliyet olarak spor yapmaktayım. Evet ☐ Hayır ☐
- Düzenli olarak sosyal faaliyet olarak müzik yapmaktayım. Evet ☐ Hayır ☐
- Düzenli olarak sosyal faaliyet olarak resim yapmaktayım. Evet ☐ Hayır ☐
- Düzenli olarak sosyal faaliyet olarak dans yapmaktayım. Evet ☐ Hayır ☐
- Her ay ders kitapları dışında kaç kitap okursunuz? Hiç ☐ 1adet ☐ 2adet ☐ 3adet 4adet 4☐ fazla ☐ ☐
- Her gün sosyal medyayı eğlence amaçlı kullanırım. Evet ☐ Hayır ☐
- Her gün sosyal medyayı oyun amaçlı kullanırım. Evet ☐ Hayır ☐
- Her gün sosyal medyayı haberleşme-iletişim amaçlı kullanırım. Evet ☐ Hayır ☐
- Matematik dersi ilgimi çeker. Evet ☐ Hayır ☐
- Fen bilgisi dersi ilgimi çeker. Evet ☐ Hayır ☐
- Matematik dersi zor bir ders olup anlamakta zorlanırım. Evet ☐ Hayır ☐
- Fen bilgisi dersi zor bir ders olup anlamakta zorlanırım. Evet ☐ Hayır ☐
- Matematik dersinden öğrendiğim bilgiler günlük yaşamda karşılaştığım birçok konuda

  işime yarar. Evet ☐ Hayır ☐
- Fen bilgisi dersinden öğrendiğim bilgiler günlük yaşamada karşılaştığım birçok konuda
  işime yarar. Evet ☐ Hayır ☐

Anketten elde edilecek veriler sadece bu çalışma için kullanılacaktır. Her bilgi saklı tutulacaktır.

Hazırlayan : Hasan küçük DAÜ Eğitim Bilimleri Doktora öğrencisi.
1 sayfa Tanılayıcı Form ve 5 Sayfa CCTDI Tutum ölçeği

CCTDI

Tutum Ölçeği

Dr. Peter A. Facione
Santa Clara Üniversitesi

Dr. Noreen C. Facione
California Üniversitesi, San Francisco

Çeviren: Gökhan İskifoğlu

Yönergenin Başlamasını Bekleyin

KATILMIYORUM (-)					KATILIYORUM (+)
1	2	3	4	5	6
Hiç Katılmıyorum	Katılmıyorum	Kısmen Katılmıyorum	Kısmen Katılıyorum	Katılıyorum	Tamamen Katılıyorum

1. Tüm seçenekleri göz önüne almak, benim için karşılanamayacak bir lükstür.	1	2	3	4	5	6
2. Tüm hayatım boyunca yeni şeyler öğrenmek harika olurdu.	1	2	3	4	5	6
3. Bir öneri için en iyi tartışma, o öneri hakkında o an hissettiklerindir.	1	2	3	4	5	6
4. Sorunum dikkatimin kolay dağılmasıdır.	1	2	3	4	5	6
5. Birbirileriyle çelişen fikirler arasında tercih yapmak çok zordur.	1	2	3	4	5	6
6. İnsanların iyi bir fikri savunmak için zayıf nedenlere güvenmeleri beni rahatsız eder.	1	2	3	4	5	6
7. Gerçek daima kendi bakış açımıza bağlıdır.	1	2	3	4	5	6
8. Farkında olmadan önyargılara sahip olabileceğim fikri beni endişelendirir.	1	2	3	4	5	6
9. Cevap vermeye kalkışmadan önce, her zaman soruya odaklanırım.	1	2	3	4	5	6
10. Büyük bir kararlılıkla olayları düşünebildiğim için kendimle gurur duyarım.	1	2	3	4	5	6
11. Çoğu şey hakkında gerçekleri hiçbir zaman öğrenemeyiz.	1	2	3	4	5	6
12. Bir konuda dört olumlu, bir olumsuz görüş varsa, olumlu olan dört görüşe katılırım.		2	3	4	5	6
13. Erkekler ve kadınlar eşit derecede mantıklıdırlar.	1	2	3	4	5	6
14. Tavsiyenin önemi, karşılığında ödediğin bedel kadardır.	1	2	3	4	5	6
15. İlkokuldaki derslerin çoğu ilginç değildir..	1	2	3	4	5	6
16. Ezberi değil, yorum yapmayı gerektiren sınavlar benim için daha iyidir.	1	2	3	4	5	6
17. Problemlerim hakkında hiçbir çözüm üretmeden saatlerce konuşabilirim.	1	2	3	4	5	6
18. İnsanlar benim fikirleri sorgulayan merakımı ve sorgulayıcılığımı takdir eder.	1	2	3	4	5	6

19. Kanıtlar yanıldığımı gösterse bile, inandıklarıma sıkı sıkıya bağlı kalırım.	1	2	3	4	5	6
20. Bariz bir şekilde hatalıysanız, düşüncelerinizi ortaya koymaya hakkınız yoktur.	1	2	3	4	5	6
21. Mantıklıymış gibi davranıyorum, ama değilim.	1	2	3	4	5	6
22. Düşüncelerimi düzenlemek benim için kolaydır.	1	2	3	4	5	6
23. Ben dahil herkes daima kendi ilgi alanı doğrultusunda tartışır.	1	2	3	4	5	6
24. Doğruluk ve yanlışlık sözkonusu olduğunda, açık fikirli olmanın da belli sınırları vardır.	1	2	3	4	5	6
25. Yaptığım parasal harcamalarımın dikkatlice kaydını tutmak benim için önemlidir.	1	2	3	4	5	6
26. Önemli bir karararla yüz yüze geldiğimde, karar vermeden önce, toplayabileceğim tüm bilgileri toplarım.	1	2	3	4	5	6
27. Tarafsız yaklaşabildiğim için arkadaşlarım karar almada benden beklenti içindedirler.	1	2	3	4	5	6
28. Açık fikirli olmak neyin doğru, neyin yanlış, olduğunu bilmemek demektir.	1	2	3	4	5	6
29. Parasal harcamaları gösteren dökümler daha anlaşılır hale getirmelidirler.	1	2	3	4	5	6
30. Diğer insanların çeşitli konular hakkında neler düşündüklerini anlamak benim için önemlidir.	1	2	3	4	5	6
31. İnandıklarımın tümü için dayanaklarım olmalı.	1	2	3	4	5	6
32. Okumak, mümkün olduğunca kaçtığım bir şeydir.		2	3	4	5	6
33. İnsanlar çok acele karar verdiğimi söylerler.	1	2	3	4	5	6
34. İlkokuldaki zorunlu dersler vakit kaybına yol açar.	1	2	3	4	5	6
35. Gerçekten çok karmaşık bir şeyle uğraşmak zorunda kaldığımda paniklerim.	1	2	3	4	5	6
36. Yabancılar her zaman kendi kültürlerini anlamaya çalışmak yerine bizim kültürümüzü anlamaya çalışmalıdırlar.	1	2	3	4	5	6
37. İnsanlar benim karar vermeyi ağırdan aldığımı düşünürler.	1	2	3	4	5	6
38. Başkalarının görüşlerine/fikirlerine karşı çıkabilmeleri için insanların nedenlere ihtiyaçları vardır.	1	2	3	4	5	6
39. Kendi inanışlarımı tartışırken tarafsız olmam imkansızdır.	1	2	3	4	5	6
40. Ortaya yaratıcı alternatifler koyabildiğim için kendimle gurur duyuyorum.	1	2	3	4	5	6

41. Doğruyu söylemem gerekirse, daha az yargılayıcı olmaya çalışıyorum.	1	2	3	4	5	6
42. Kendimi sık sık insanların argümanlarını/iddialarını değerlendirirken bulurum.	1	2	3	4	5	6
43. Neye inanmak istiyorsam ona inanırım.	1	2	3	4	5	6
44. Zor problemleri çözmek için uğraşmayı sürdürmek kısacası önemli değildir.	1	2	3	4	5	6
45. Fikirlerimi savunmak zorunda bırakılmamalıyım.	1	2	3	4	5	6
46. Başkaları, kararların uygulanmasında mantıklı standartların belirlenmesi için bana danışırlar.	1	2	3	4	5	6
47. Zorlayıcı konuları öğrenmeyi heycanla beklerim.	1	2	3	4	5	6
48. Yabancıların ne düşündükleri üzerinde çalışmak anlamlıdır.	1	2	3	4	5	6
49. Sorgulayıcı oluşum en güçlü yanlarımdan birisidir.	1	2	3	4	5	6
50. Görüşlerimi destekleyecek olguları ararım, görüşlerime karşıt olanları değil.	1	2	3	4	5	6
51. Karmaşık problemleri çözmeye çalışmak eğlencelidir.	1	2	3	4	5	6
52. Başkalarının düşüncelerini anlama yeteneğimden dolayı takdir edilirim.		2	3	4	5	6
53. Benzetmeler ancak karada yüzücü paleti ile yürümek kadar kullanışlıdır.	1	2	3	4	5	6
54. Beni mantıklı biri olarak tanımlayabilirsiniz.	1	2	3	4	5	6
55. Herhangi birşeyin nasıl çalıştığını anlamak bana büyük zevk verir.	1	2	3	4	5	6
56. İşler zorlaştığında, arkadaşlarım sorunu çözmek için bana gelirler.	1	2	3	4	5	6
57. Bir problemle karşılaşıldığında, ilk yapılması gereken şey problemin ne olduğunu iyice anlamaya çalışmaktır.	1	2	3	4	5	6
58. Tartışmalı konulardaki fikrim genellikle en son konuştuğum kişiye bağlıdır.	1	2	3	4	5	6
59. Konu ne hakkında olursa olsun, daha fazlasını öğrenmek için can atarım.	1	2	3	4	5	6
60. Bir çözümün diğerinden daha iyi olup olmadığını bilmenin hiç bir yolu yoktur.	1	2	3	4	5	6
61. Soruları çözmenin en iyi yolu, yanıtları başkasından istemektir.	1	2	3	4	5	6
62. Bir çok soru sorulamayacak kadar ürkütücüdür.	1	2	3	4	5	6
63. Karmaşık problemlere karşı düzenli yaklaşımımla tanınırım.	1	2	3	4	5	6

64. Farklı dünya görüşlerine karşı açık fikirli olmak, insanların düşündüğü kadar önemli bir şey değildir.	1 2 3 4 5 6
65. Öğrenebileceğin her şeyi öğren, ne zaman işe yarayacağını bilemezsin.	1 2 3 4 5 6
66. Hayat bana aşırı mantıklı olmamak gerektiğini öğretti.	1 2 3 4 5 6
67. Her şey göründüğü gibidir.	1 2 3 4 5 6
68. Bir problem üzerinde uğraşmam gerektiğinde, diğer şeyleri kafamdan tamamıyle çıkartabilirim.	1 2 3 4 5 6
69. Diğer insanlar, sorunun çözüm kararını alırken bana danışırlar.	1 2 3 4 5 6
70. Kafamda bir fikir oluşmuşsa, seçenekleri değerlendiriyor gibi davranmama gerek yoktur.	1 2 3 4 5 6
71. Güçlü kişiler doğru cevabı kolayca belirleyebilirler.	1 2 3 4 5 6
72. Pek çok soruya hangi standartları uygulayacağımızı bilmek imkansızdır.	2 3 4 5 6
73. Başkaları her ne kadar kendi fikirlerini ortaya koysalarda benim onları duymaya ihtiyacım yoktur.	1 2 3 4 5 6
74. Karmaşık problemlerin çözümüne yönelik düzenli planlar geliştirmede iyiyimdir.	1 2 3 4 5 6
75. İnsanların benimle aynı fikirde olmalarını sağlamak için işe yarayabilecek her türlü sebebi gösterebilirim.	1 2 3 4 5 6

Anket sona ermiştir.

Teşekkür ederim.

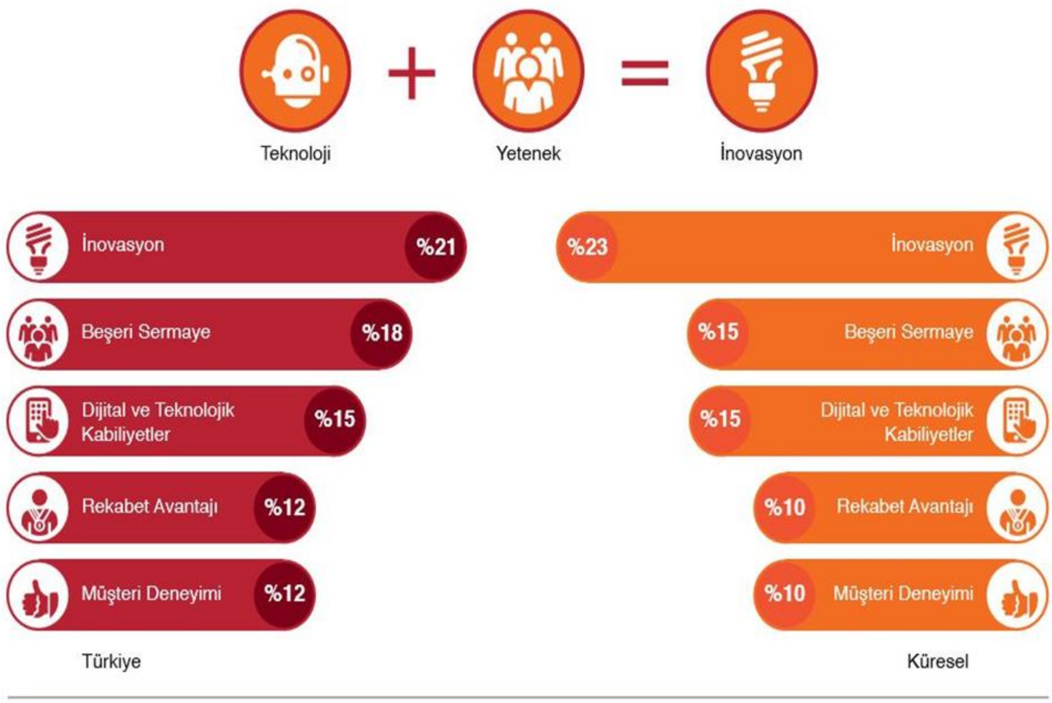
Appendix J: Teacher's Handbook Booklet

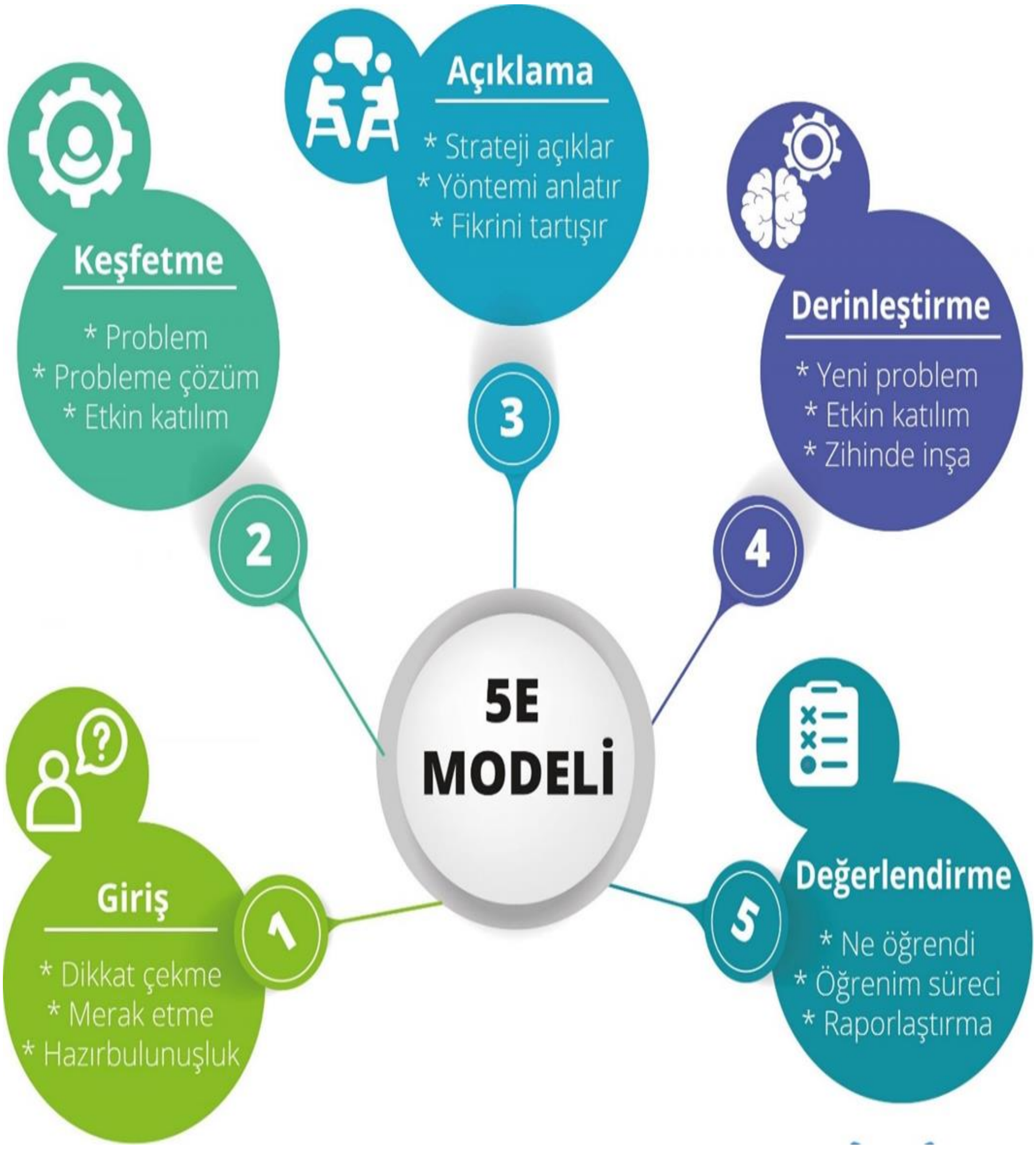
21. Yüzyıl içerisinde gelişmiş ülkeler arasında üretim, buluş yapma ve teknolojik gelişme alanlarındaki yarış iyice hızlanmıştır. Yeni teknolojilerin ve buluşların ekonomiye entegrasyonu, bütün ülkelere ekonomik büyüme ve refah imkânları sağlamaktadır. STEM eğitimi Fen, Teknoloji, Mühendislik, Matematik disiplinleri arasındaki ayırımı ortadan kaldırarak, bu disiplinler arasında tam bütünleşmeyi uyumlu bir şekilde oluşturarak, anaokulundan üniversiteye kadar verilecek proje tabanlı eğitim yaklaşımıyla; soru soran, araştıran, üreten ve yeni buluşlar yapabilen bir neslin yetiştirilmesini amaçlamaktadır. STEM eğitim yaklaşımıyla, öğrencilerin üretim ve buluş yapma alanında yaratıcı düşünme, eleştirel düşünme, problem çözme gibi 21.yy becerilerinin kazandırılması hedeflenmektedir. Dünya merkez Bankası (2019)tarafından açıklanan rekabet edebilirlik ve verimliliğin öne çıkacağı yeni iş dünyasında her öğrenci tem el becerilere sahip olması gerekmektedir. Öğrenciler, iş dünyasına girdiklerinde de temel ve proje becerileri sayesinde iş hayatının istediği niteliklere kolayca uyum sağlayabilmeleri amaçlanmaktadır.

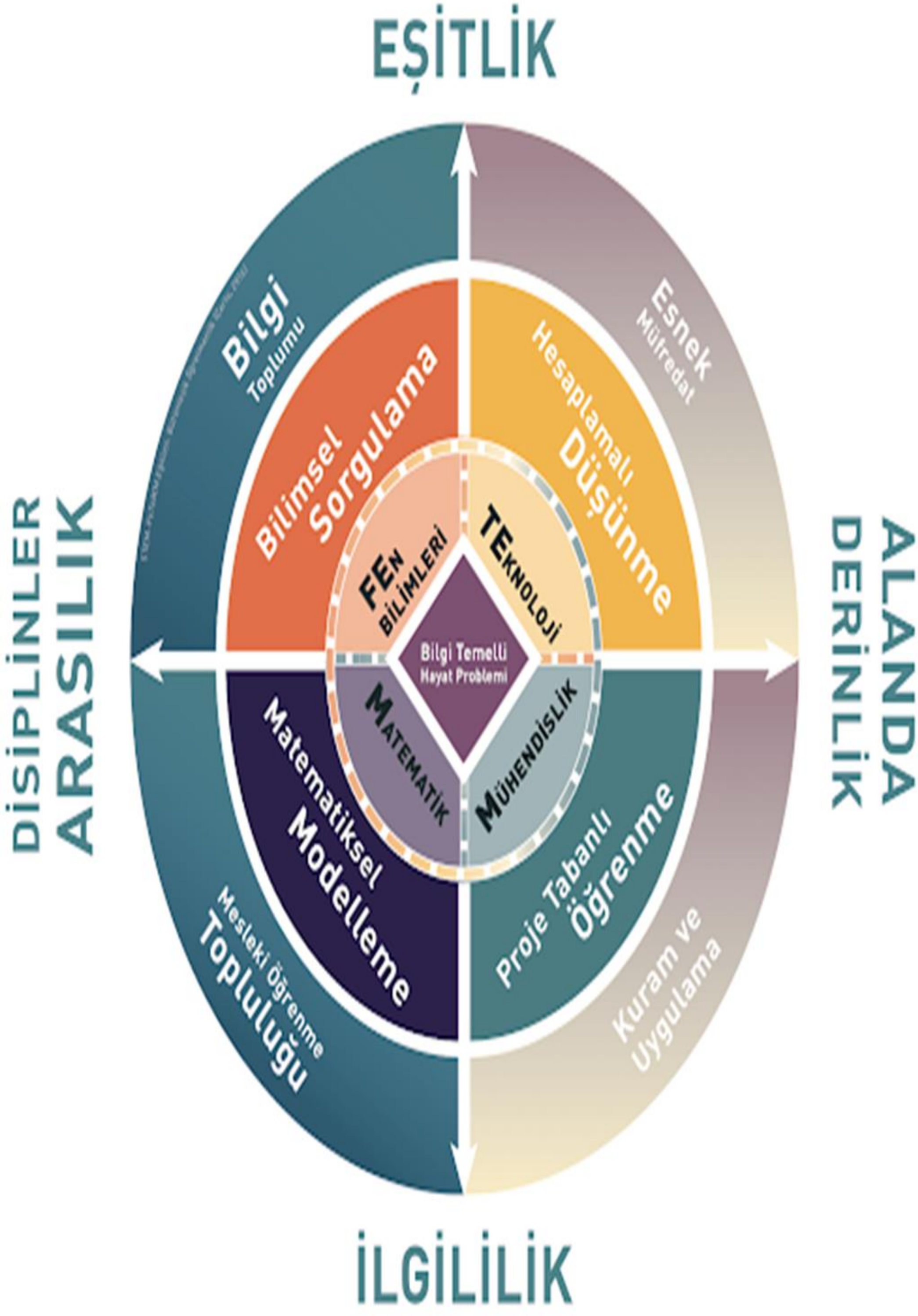
STEM okuryazarlığı, yani bilim, teknoloji, mühendislik ve matematiğin doğasına ilişkin farkındalık ve her disiplinden bazı temel kavramlara aşinalık, tüm öğrenciler için bir eğitim önceliği olmalıdır (Bybee, 2010; National Academy of Engineering ve Ulusal Araştırma Konseyi, 2014).

İlgili literatür araştırmalarına göre, STEM eğitimi, bilim, teknoloji, mühendislik ve matematiğin dört disiplinini ayıran geleneksel engelleri ortadan kaldıran ve bunları öğrenciler için gerçek dünya, titiz ve ilgili öğrenme deneyimlerine entegre eden, öğrenmeye yönelik disiplinler arası bir yaklaşımdır.

21. Yüzyıl içerisinde gelişmiş ülkeler arasında üretim, buluş yapma ve teknolojik gelişme alanlarındaki yarış iyice hızlanmıştır. Bu yarış ortamı bütün ülkeleri bilime, mühendisliğe ve yenilikçi teknolojilere yatırım yapmaya yönlendirmektedir. Yeni teknolojilerin ve buluşların ekonomiye entegrasyonu, bütün ülkelere ekonomik büyüme ve refah imkânları getirmesine olanak sağlanmıştır.

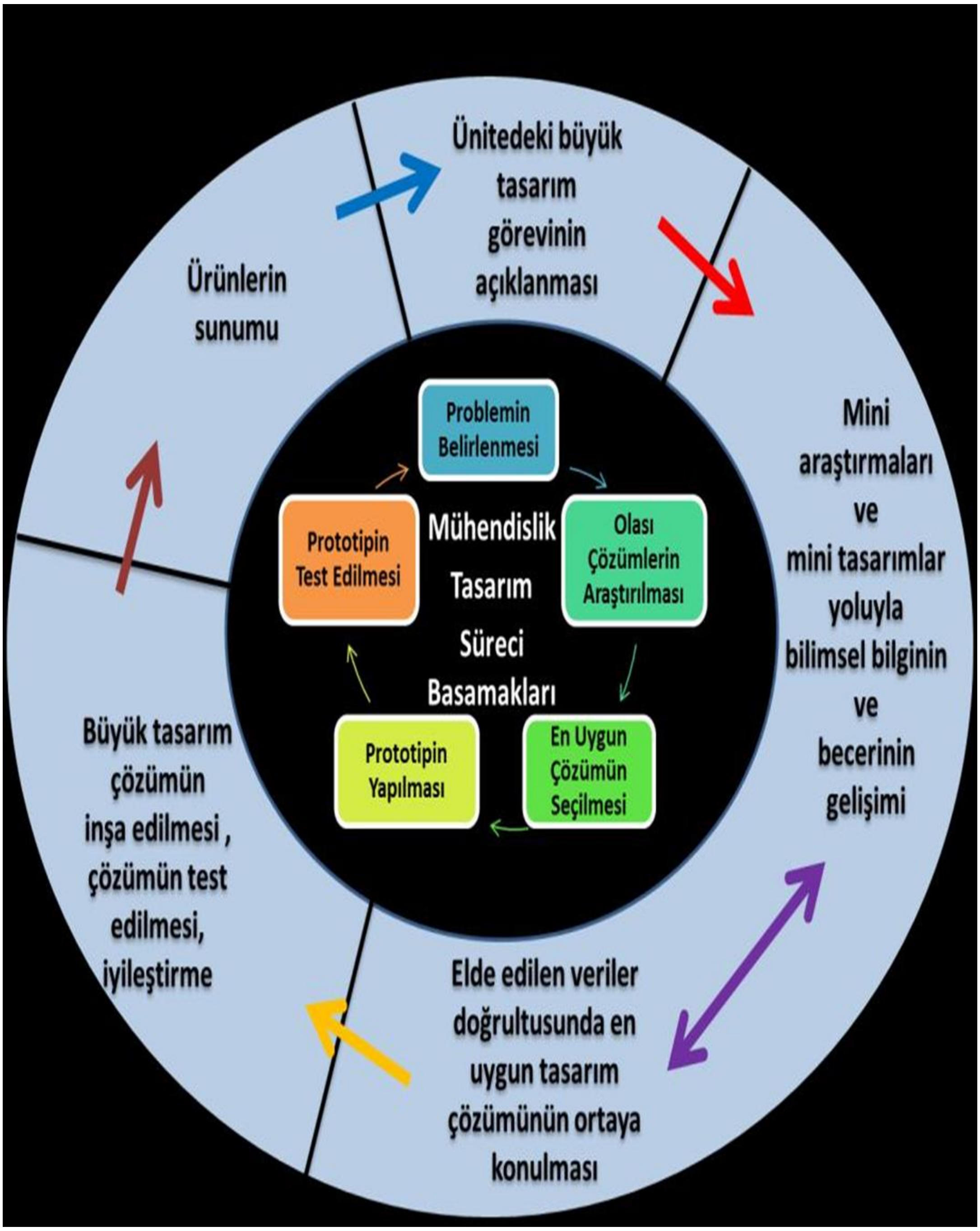


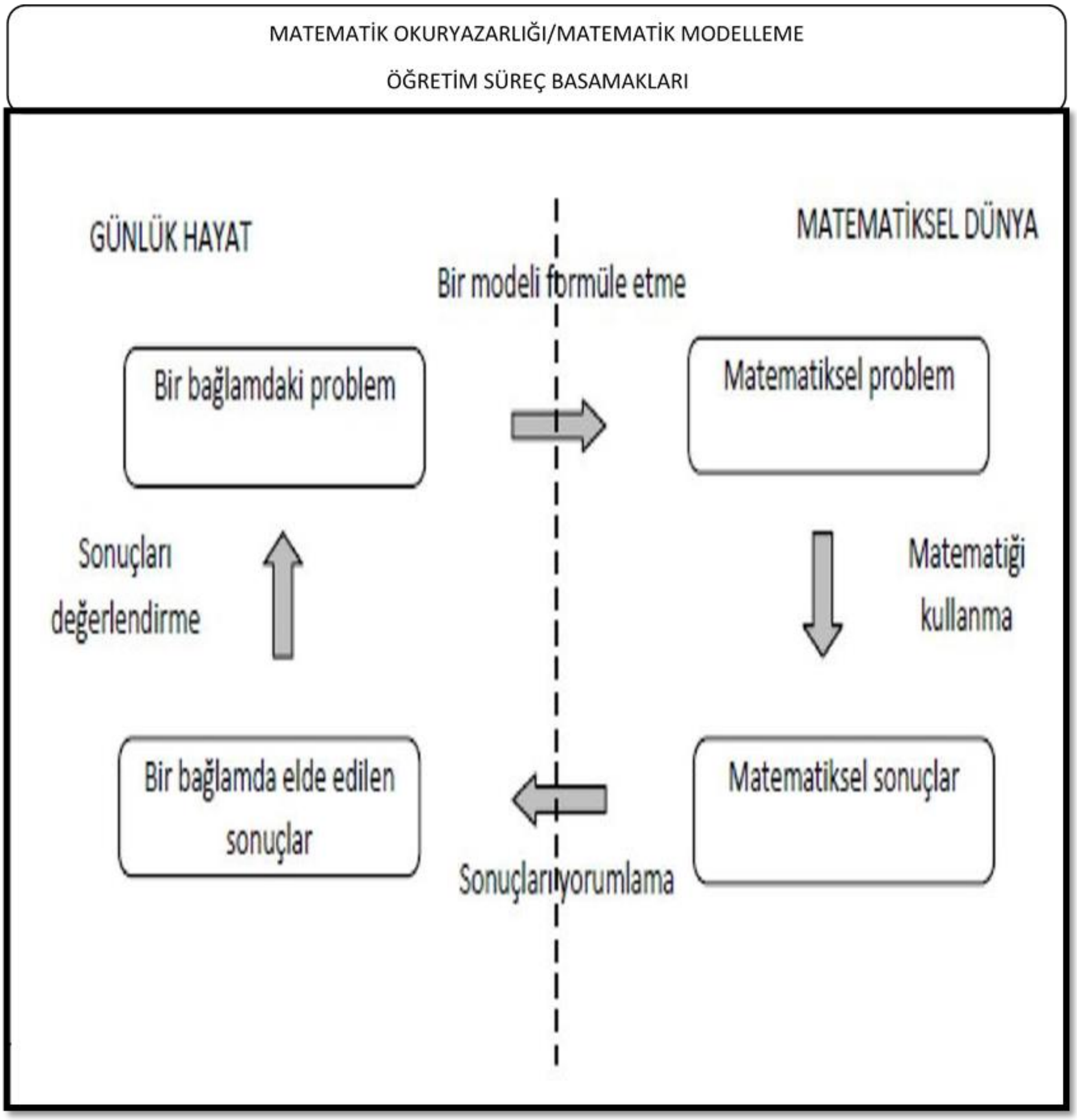

Açıklama
* Strateji açıklar
* Yöntemi anlatır
* Fikrini tartışır
Keşfetme
* Problem
* Probleme çözüm
* Etkin katılım
Derinleştirme
* Yeni problem
* Etkin katılım
* Zihinde inşa
3
2
4
5E
MODELİ
Giriş
* Dikkat çekme
* Merak etme
* Hazırbulunuşluk
1
5
Değerlendirme
* Ne öğrendi
* Öğrenim süreci
* Raporlaştırma



EŞİTLİK
DİSİPLİNLER ARASILIK
ALANDA DERİNLİK
İLGİLİLİK
Bilgi Toplumu
Esnek Müfredat
Mesleki Öğrenme Topluluğu
Kuram ve Uygulama
Bilimsel Sorgulama
Hesaplamalı Düşünme
Matematiksel Modelleme
Proje Tabanlı Öğrenme
FEN BİLİMLERİ
TEKNOLOJİ
MATEMATİK
MÜHENDİSLİK
Bilgi Temelli Hayat Problemi


21.Yüzyıl Becerileri
Öğrenme ve Yenilenme Becerileri
*Yaratıcılık ve Yenilenme
*Eleştirel Düşünme ve Problem Çözme
*İletişim ve İşbirliği
Bilgi,Medya ve Teknoloji Becerileri
*Bilgi Okur-Yazarlığı
*Medya Okur-Yazarlığı
*Bilgi ve İletişim Teknolojileri (ICT) Okur-Yazarlığı
Yaşam ve Meslek Becerileri
*Esneklik ve Uyum
*Girişimcilik ve Öz-Yönelim
*Sosyal ve Kültürlerarası Beceriler
*Üretkenlik ve Sorumluluk
*Liderlik ve Sorumluluk


Ünitedeki büyük tasarım görevinin açıklanması
Mini araştırmaları ve mini tasarımlar yoluyla bilimsel bilginin ve becerinin gelişimi
Elde edilen veriler doğrultusunda en uygun tasarım çözümünün ortaya konulması
Büyük tasarım çözümün inşa edilmesi , çözümün test edilmesi, iyileştirme
Ürünlerin sunumu
Mühendislik Tasarım Süreci Basamakları
Problemin Belirlenmesi
Olası Çözümlerin Araştırılması
En Uygun Çözümün Seçilmesi
Prototipin Yapılması
Prototipin Test Edilmesi



Okuryazarlığın içselleştirilmesi-Duyuşsal Alan

Fen Bilim Okuryazarlığı: Doğal dünyayı anlamak için bilimsel bilgi ve süreci kullanma becerisinin yanı sıra doğal dünyayla ilgili tartışmalara katılma yeteneğini ifade eder.

Teknoloji Okuryazarlığı: Öğrencilerin yeni teknolojileri nasıl kullanacaklarını bilmeleri, yeni teknolojilerin nasıl geliştirildiğini anlamaları ve yeni teknolojilerin dünyayı nasıl etkilediğini analiz etme becerisi kazanmaları gerektiği anlamına gelir.

Mühendislik Okuryazarlığı: Teknolojilerin mühendislik tasarım süreci boyunca, entegre ve disiplinler arası bir yaklaşım tarzı ile proje tabanlı dersler kullanılarak nasıl geliştirildiğini anlamayı ifade eder.

Matematik Okuryazarlığı: Matematiksel problemleri ortaya koyarak, formüle ederek, çözerek ve yorumlayarak analiz etme, akıl yürütme ve fikirleri etkili bir şekilde ifade etme becerilerini ifade eder (Armknecht, 2015; Thomasian, 2011).

Tasarım Okuryazarlığı: Tasarımsal kesitlerle, matemetiksel kavram ve şekiller ile çevresel yaşam döngüsü içerisinde şekil, renk ve tasarımsal uyumu anlatır.

STEAM ÖĞRETİM MODELİ; FARKLI DERSLERDEKİ KAZANIMLARI DÖNEM BAŞI BELİRLENECEK UYGUN PROJE KONU İLE İLİŞKİLENDİREREK DERS KAZANIMLARIN ÖĞRETİLMESİ HEDEFLENİR.

BELİRLENECEK KONU YAKINDAN UZAĞA YAŞAMSAL YEREL VEYA EVRENSEL PROBLEMLERLE İLİŞKİLENDİRİLMESİ GEREKMEKTEDİR. BELİRLENEN PROBLEM CÜMLESİ VE PROBLEME YÖNELİK 5E SORULARI SADEC ÖNE HAZIRLIK KABUL EDİLİR. DERS MATERYALLERİ HER TÜRLÜ İMKANA GÖRE ÖĞRETMENİN YARATICILIĞINA BAĞLIDIR.

STEAM ÖĞRETİM MODELİ ZAMAN ODAKLI DEĞİL, SÜREÇ ODAKLI PERFORMANS GÖZLEMİ YAPILIR.

ÖĞRENCİNİN AKTİF OLARAK DERSE KATILIP, SÜREÇİ SINIF ORTAMI DIŞINDA DA DEVAM ETMESİ HEDEFLENİR.

ESAS ÖĞRENME SORUSU "NEDEN ÖNEMLİDİR? " HER ZAMAN ÖN PLANDA TUTUP, ÖĞRENCİNİN DUYUŞSAL ALANDA PROBLEMİ İÇSELLEŞTİRMESİ BEKLENİR.

STEAM PROJE DERSİ DEĞİL, DÖNEM BAŞI BELİRLENECEK YAŞAMSAL PROBLEMİ PROJE TEMELİNDE , 5 DERS-FEN BİLİMLERİ, TEKNOLOJİ, MÜHENDİSLİK, TASARIM VE MATEMATİK DERSLERİ İŞLENİRKEN KAZANIMLARI BELİRLENEN PROJEYE YÖNELİK DERSLERİN İŞLENMESİDİR.

STEAM ÖĞRETİM MODELİ HER DERSTE UYGULANIRKEN İLKÖĞRETİM DÜZEYİNDE MATEMATİK VE FEN BİLGİSİ DERSLERİ TEMEL DERSLER KABUL EDİLİR. TEKNOLOJİ VE MÜHENDİSLİK DÜŞÜNME BECERİLERİ İKİ TEMEL DERS İÇİNDE DERS İŞLEYİŞİNDE İLİŞKİLENDİRLİR.

STEAM ÖĞRETİM MODELİ UYGULANIRKEN ÖĞRETMENE EK DERS YÜKÜ GETİRMEZ. 5E ÖĞRENME MODELİ AŞAMALARI, AÇIKLAMALAR VE ÖRNEK SORU KÖKLERİ DİKKATE ALINMASI GEREKİR.

STEAM ÖĞRETİM MODELİ HER SINIFTA YUKARIDA BELİRTİLEN ÖN HAZIRLIK DAHİLİNDE HER ÖĞRETMEN TARAFINDAN UYGULANABİLİR.

Modelin Aşamaları	Aşamaların Açıklaması
Dikkat Çekme, Ön Öğrenmeleri Ortaya Çıkarma, Öğrenme Etkinliğine Girme (Engage) Anahtar Soru: Ne?-Ana konuya odaklanır.	Bir olay, durum ya da problemden hareketle öğrencilerin ilgileri ve meraklarının çekilmesi beklenir. Önceki bilgiler ve gelecekteki öğrenilecek kavramlar arasında ilişki kurulur. (Bybee, 1997).
Araştırma, Keşfetme (Explore) Anahtar soru: Çözümü keşfedin; Nasıl? Bazı detaylar vermek, hepsini değil.	Öğrenciler düşüncelerini ortaya koymak için araştırmalar yapar. Yapılan araştırmalar modelin ilk aşamasındaki soruya ya da sorulara yanıt olabilir. Araştırmalar, modelin temelini oluşturur (Bybee, Taylor, Gardner, Van Scotter, Powell, Westbrook ve Landes, 2006). Öğretmen bu aşamada gruplara tartışmaları için sorular sorar ve onlara rehberlik eder. Öğretmen öğrencilerin kendi düşüncelerini ortaya koyabilecekleri, onların ihtiyaç duyduğu zaman ve materyalleri temin eder (Bybee 1997; Bybee ve diğerleri, 2006).
Açıklama (Explain) Anahtar soru: Bu mu? Yeni fikirleri keşfetmek.	Öğrenciler kavramlarla ilgili elde ettikleri bilgileri ya da süreçte geçirdikleri yaşantıları açıklar. Öğretmen bu aşamada çeşitli yöntem ve teknikleri ihtiyacına göre kullanıp süreçteki açıklamaların zenginleşmesini sağlar (Bybee ve diğerleri, 2006). Açıklama kısmı, modelin en kısa aşamasıdır. Çünkü bundan sonra gelen transfer

	etme/derinleşme aşaması öğrencilerin bilgilerini yapılandırmalarını ve kavramları biraz daha genişletmelerini içerir (Trowbridge, Bybee ve Powel, 2004).
Transfer Etme, Derinleşme (Elaborate) Anahtar Soru: Test edin; Hangisi? Bulguları uygulamak ve alternatifleri tartışın.	Önceki üç aşamada geçirilen yaşantılara ve elde edilen bilgilere dayanır. Öğrenciler elde ettikleri bilgiler yardımıyla kavramları yeni durumlara transfer eder. Bybee göre, (1997; 181) bu aşamanın en önemli amacı: "Sürecin, becerilerin ve kavramların genelleştirilmesidir." Transfer/derinleşme aşaması öğrencilere kavram yanılgılarını düzeltmeleri ve anlamlarını güçlendirmesi için önemli fırsatlar verir (Bybee ve diğerleri, 2006).
Değerlendirme (Evaluation) Anahtar Soru: Ne zaman? Öğrenme çıktılarını sunun ve farklı referansları birbirine bağlayın.	Öğrencilerin anlama düzeyi bu aşamada belirlenir (Bybee ve diğerleri, 2006). 5E modeli içerisinde değerlendirme aşaması, süreç sonunda öğrenme ürünlerini kontrol etmek açısından dikkat edilmesi gereken bir aşamadır; fakat gözden kaçırılmaması gereken nokta, 5E modeli kullanılırken değerlendirmenin, her aşama sonunda gözlemlerle, öğrenci katılımlarının niteliklerinin kontrolü ile sağlanması gerekir (Öztürk, 2008).

Ders Süresince!

Aşamalar	Öğretmenin Yapması Gerekenler
Girme/Giriş Konu içeriği standart-anahtar kavramlara dikkat ediniz	Öğretmen derse katılımı sağlamak için bu modele uygun olarak her zaman ilgi çeker, merak uyandırır. Öğretmen sorular sorar ve konuyu anlatmadan bu konuyla ilgili neler bildikleri hakkında fikir sahibi olur.
Keşfetme Büyük fikirler ortaya koyarken anahtar kavramlara bağlı kalınız	Öğrencileri birbirleriyle etkileşimli biçimde çalışmaya teşvik etmek ve çalışma süresince duruma doğrudan müdahale etmemek öğrencileri gözlemlemek, dinlemek ve merak uyandırıcı sorular sormak. Tartışmaları gerekli olduğu zamanlarda farklı yöne veya konuya çekmek. Ayrıca öğrencilere problemlerle başa çıkabilecekleri kadar zaman tanımak ve her zaman bir rehber olarak davranmak
Açıklama Öğrencilerin bildiklerini belirleyin ve yapabilme yönünde cesaretlendiriniz Anahtar-temel soruları (yönlendirici sorular) sorunuz,	Öğrencilerin kendi kavramlarını ve açıklamalarını kendi kelimeleri ile izah etmelerine izin vermek. Her zaman öğrencilerden söyledikleri ifadelerle ilgili kanıt ve bunları genişletmelerini istemek, formal tanımlar yapmalarını sağlamak/ yapmak, gerekli yerlerde açıklamalar yapmak, kavramların anlatımında öğrencilerin deneyimlerini kullanmak.

Derinleşme Proje tabanlı öğrenme ile disiplinler arası veya disiplinler(diğer dersler) arası öğrenme etkinlikleri tasarlayınız	Öğrencilerin formal tanımlamaları ve açıklamaları kullanmasını beklemek, yeni kavramları ve becerileri yeni durumlarda kullanmalarına teşvik etmek, alternatif açıklamalara yönlendirmek ve buna dair fikir vermek, elde ettikleri verilerle ve kanıtlarla ilgili "Ne biliyorsunuz?", "Niye böyle düşünüyorsunuz?", "Nasıl kanıtlarsınız?" gibi sorular sormak.
Değerlendirme	Öğrencileri yeni kavramları uygularken ve becerilerini geliştirirken gözlemlemek. Bilgilerini ve becerilerini değerlendirmek. Öğrencilerin kendi düşüncelerini ve davranışlarını değiştirip değiştirmediklerine dair gözlem yapmak. Öğrencilerin kendi becerilerini değerlendirebilecekleri ortamlar oluşturmak. "Niye böyle düşünüyorsunuz?", "Ne gibi bir kanıta sahipsiniz?", "Bunu nasıl açıklarsınız?" şeklinde açık uçlu sorular sorarak öğrencilerin kendi öğrenmelerini değerlendirmelerini sağlamak.