Doi: 10.30473/IDEJ.2023.68191.1161 ISSN: 2588-4476

Iranian Distance Education Journal

Vol. 4, No. 1, (New Series) Winter-Spring 2023 (P 143-153), Payame Noor University

Original Article

Effects of the Stem Approach on Students' Problem Solving Skill in Science Education

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Received: 2022/06/22 **Accepted:** 2022/10/22

Abstract

This study is investigated the effectiveness of science education with STEM approach, in a combined (face-to-face and virtual) method, on problem solving skill of the students of the middle school in the topic of energy. This research is a semi-experimental and pre-test-post-test type with the control group. The statistical population is all the 7th-grade male students from middle school in Tabadakan region, Mashhad 2021-2022. From this statistical population, 70 students were selected by the convenience sampling who were in two classes. One of the classes was randomly selected as the experimental group and the other as the control group. The control group received training through the traditional approach, whereas the experimental group underwent training using the STEM method. The research tool was Hepner and Patterson's (1988) standard problem solving skill questionnaire. In order to develop lesson plan with STEM approach, the proposed standard framework (STE(A)M IN INTEGRATED LEARNING SCENARIO) was used. Data from questionnaires was analyzed using SPSS, with statistical indicators calculated and normality. Also, hypotheses investigated using Kolmogorov-Smirnov tests and covariance analysis. The significant values obtained for problem-solving skill (0.033) and its subscales, including Confidence (0.022), Approach-Avoidance style (0.046) and Personal Control (0.025), indicated that the STEM approach was helpful in improving learners' learning and strengthening their problem-solving skill. Also, this study showed that students generally have difficulty learning scientific concepts and problem solving skills, but hybrid approaches such as STEM can improve educational processes and learner performance in developing countries such as Iran. Therefore, the role of STEM approach in education becomes highlighted.

Keywords

Science education, STEM approach, Problem-solving skill.

Introduction

STEM approach has achieved a special position among the new approaches for teaching as the result of educational reform implementations (Siekmann & Korbel, 2016). STEM is an approach that unifies different concepts and procedures of each STEM component (Science, Technology, Engineering, and Mathematics) in an only unit in the learning procedure (Sari & Herlina, 2021). Teaching STEM is not the only strategy, but it is a wide range of strategies for helping the learner in implementing concepts and skills relevant to various majors to solve the problems significantly (Vasquez, 2015). STEM approach helps the students get ready for encountering the age of globalization that is growing fast. Learning based on STEM asks students to be innovators, problem solvers, and creators who have confidence, are aware of technology and think logically

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(Krasnova & Shurygin, 2020). The students cannot be qualified for a job in the age of competition and technology progress without having a strong base of science, technology, engineering, and mathematics. The overall purpose of learning with STEM is to implement and practice the basic content (Stute et al., 2020).

Science education is an integral part of national and state standards for early childhood classrooms which encompasses content-based instruction as well as process skills, creativity, experimentation, and problem-solving. By introducing science in developmentally appropriate ways, we can support children's sensory explorations of their world and provide foundational knowledge and skills for lifelong learning as well as an appreciation of nature (Cabe Trundle 2015).

On the other hand, Corona virus disease has influenced all the aspects of human life such as cultural, economic, political, educational, and research aspects. This pandemic has also influenced science education and changed it inevitably. One of these changes was choosing blended education. Blended learning is a combination of teaching face-to-face and virtual (Osguthorpe & Graham, 2003).

Staker and Horn (2012) present a kind of classification of four models of blended learning that is reduced from six main models. These six models include; 1) face-to-face deriver, 2) rotation model, 3) Flex model, 4) online lab model, 5) self-blend model, and 6) enriched virtual model. Staker and Horn decided to remove the first model because of no significant difference between this model and the second and third ones and they blended the fourth and fifth. This decision kept the rotation, Flex, self-blend, and enriched virtual models. These two researchers pointed to different kinds of rotation models. The most interesting kind of rotation model is the "flipped classroom". In this situation, student studies virtual in the place that she or he has selected to receive the training contents.

There have been many years that the education system of Iran has forced the students to memorize and repeat scientific concepts by applying traditional methods and approaches. However, most advanced educational systems in the world have quit traditional approaches to education such as teacher-centered methods, and teaching methodology such as lecturing, and they have used new methods for learning and teaching. Moreover, the performance of Iran in international exams such as TIMSS in recent years shows that the educational methods and approaches seriously need to be changed, up-to-date, and revised. Iran ranked 43 among 47 countries in TIMSS evaluations performed by the 4th-grade primary students in the experimental science course in 2015 (TIMSS, 2015). Further, it ranked 27 among 39 countries in the performance of 8th-grade students. In addition, the same exam was performed by the 4th-grade primary students in the experimental science course in 2019 and Iran ranked 48 among the 58 countries, and it ranked 32 among 39 countries by the 8th-grade students' performance (TIMSS, 2019).

Problem-solving is a procedure to properly explore, sequence, and arrange directions that lead to an objective with a solution. When humans face a problem, they should overcome the problem and obstacles to reach their goal. Thus, the main factor in solving the problem is implementing the previous experiences to find a solution that was not known before. At least the experience, knowledge, and the previous skill are the prerequisite to solving the problem in a situation that the person is (Saygili et al., 2009 & Thompson et al., 2003).

Numerous factors can prevent problem-solving skill growth among students and one of these factors is traditional education approaches. The dominant style is inactive in most educational classes; it means that the students are less exposed to challenging situations in terms of the course concepts. Therefore, they experience fewer opportunities for interaction, consensus, cooperation, and discussion between teachers and themselves. Further, the students are encouraged to have parrot repetition, competition is replaced with cooperation, and the possibility of social phobia and seclusion increases among them (David Johnson & Roger Johnson, 2018).

Therefore, it is necessary that the teachers notice the importance of the STEM approach and its role in teaching and learning procedure. It is expected that an appropriate approach is implemented after recognizing and gaining awareness and the conditions be prepared for promoting problem-solving skills among the students to find suitable solutions for their new problems in the future. Various studies have been conducted in terms of the impact of the STEM approach, necessity, and effect of this new approach on different variables.

In the article titled "the impact of STEM training approach in blended learning for improving the students' critical thinking skill", Sulisworo et al (2020) from Indonesia Dalan Ahmad University investigated the effect of blended learning of physics (fluid dynamics topic) with STEM approach on the students' critical thinking skill compared to the common teaching method in a school from a rural area. Considering the limitations and problems such as the limited time of face-to-face meetings, the low attention of students to the teacher, the low self-confidence of students, etc., the researchers used the schoology website for blended learning. Tools for observation are the essay questions adopted from Ennis and the criteria for scoring have also been determined. Among the limitations of this study, limited digital literacy has been reported in some students. The results of the article showed that blended learning with STEM training approach promotes the student's critical thinking skill in comparison to common learning. From the point of view of the authors of the article, this result due to learning activities be which involve students more actively and the teacher only plays a role as a facilitator and learning is student-centered.

Li et al (2020) in a study with the title of "Research and trends in STEM education: a systematic review of journal publications" performed a systematic review of STEM education scholarship development based on existing journal publications from 2000 to 2018. They identified three main challenges in conducting such a review: (1) the interdisciplinary nature of STEM education, (2) the diversity of journals that publish STEM education research, and (3) difficulties in deciding how to establish the scope of the literature review. To address these challenges, the authors used a comprehensive search strategy that included multiple databases and a broad range of journals. They also developed a coding scheme to analyze the publications and identify trends in research topics, methods, and journal categories. The authors concluded that STEM education scholarship has been growing rapidly over the past two decades, with a focus on teacher education and professional development, curriculum and instruction, assessment and evaluation, diversity and equity, informal and out-of-school learning, technology and multimedia, and cognitive and learning sciences. They also noted that STEM education journals have been collectively developing their own professional identity, but there is still much individual journal-based performance. The authors suggested that their review provides a valuable resource for researchers, practitioners, and policymakers interested in STEM education.

Serin et al (2009) in the article titled "The effect of educational technologies and material supported science and technology teaching on the problem solving skills of 5th grade primary school student" used a quasi-experimental design with pre and post tests, a control group and a reliable data collection device to measure problem solving skills. The researchers noted that the experimental group received the constructivist approach via oriented educational technologies and supported teaching material, while the control group received the traditional teaching of lessons appropriate to the Ministry of Education Science and Technology program. The educational software used in the research was prepared with the Macromedia Flash 8 program. The authors provide a clear description of the methodology, hypotheses, and results of the study, and show that the use of educational technologies can be an effective tool for improving problem solving skills in primary school students.

The article "The effect of project based learning-STEM on problem solving skills for students in the topic of electromagnetic induction" was written by Yuliati et al (2020). Their study aimed to clarify the impact of PjBL-STEM on the students' problem-solving skills in the electro-magnetic induction topic with a non-equivalent quasi-experimental group design. The study

involved two classes, one using PjBL-STEM and the other using PjBL without STEM. The results of the article showed that PjBL-STEM had a significantly higher impact on improving students' problem-solving skills than PjBL alone. The authors also found that students in both classes had a positive response towards the implementation of the learning model. In general, this article highlights the importance of understanding the abstract concept of electromagnetic induction and the role of PjBL-STEM in enhancing students' problem-solving abilities in STEM subjects.

The article "The Effect of STEM-Based Education Program on Problem Solving Skills of Five-Year-Old Children" was written by Sahin (2021). The article presents a study on the effectiveness of a STEM-based education program in improving problem-solving skills in preschool children. The study involved an experimental group that received the STEM program and a control group that followed the regular preschool curriculum. The researcher compared the pre-test and post-test scores on the Problem Solving Skills Scale (PSSS) between the two groups. The results of the article show that the total PSSS score was significantly higher in the experimental group. The author concluded that the STEM-based education program can effectively enhance problem-solving skills in preschool children.

Malçok and Ceylan in their review with the title of "Does STEM education have an impact on problem solving skill?" They investigated the relationship between the STEM based on engineering design procedures and the problem-solving skills. Moreover, the article investigates the studies relevant to STEM and problem-solving skills in Turkey (MALÇOK & CEYLAN, 2020).

Here, we have tried to compare the effect of science education in blended learning, using the traditional approach and the STEM approach on the problem-solving skills of the students of first secondary school on the topic of energy. In other words, we answer the question whether there is a significant difference between the levels of problem-solving skills of students who are taught the subject of energy through the STEM approach and students who are taught through the common method?

Methodology

This study is quasi-experimental with pre-test and post-test and with the control group. The statistical population is all the 7^{th}-grade male students from the middle school in the Tabadakan region, Mashhad 2021-2022. The sample of this study was 70 7^{th}-grade male students. 39 of them entered the control group and 31 students entered the experimental group. Further, they were selected via convenience sampling. The students of four classes, two schools were selected as the participants of this study. Two classes were determined as experimental groups and two classes were determined as control groups. Training in the control group was done with the traditional approach and training in the experimental group was performed via the STEM approach.

Heppner's Problem-Solving Inventory (Heppner, 1988) was used with 35 items and three subscales that included Problem Solving Confidence, Approach-Avoidance style, and Personal Control to evaluate the problem-solving skill. The scoring key of this questionnaire has a 6-point Liker scale with the low scores showing the highest awareness level from the problem-solving skill. The score that the student receives from this questionnaire in this study indicates his/her skill level of problem-solving skills. The reliability of this questionnaire has been reported at .89 and .83 based on two times running in two weeks. Regarding the investigated Cronbach's alpha for Problem Solving Confidence (.85), Approach-Avoidance style (.84), and Personal Control (.72), there was an appropriate and acceptable internal consistency between the factors (Clark, 2002). Further, the researcher gained .88 from Cronbach's alpha for this questionnaire. Considering that this value is more than .7, the reliability of the questions was confirmed.

Research procedure

Procedure

The Problem-Solving inventory of Heppner was distributed to both groups of participants to determine their levels of problem-solving skill and their score was regarded as pre-test scores. Both groups had an almost similar result in this phase. The experimental variable (blended learning with STEM approach) with 9 sessions of 80 minutes (one chapter in each session) was performed in a science course, including energy and its transformation, energy source, heat, and optimization of energy consumption after making sure of the relative homogeneity of students' problem-solving skill in two classes. The experimental group was educated via blended learning (rotation, and flipped classroom models), Shad application (an application that teachers use for students' virtual education in Iran), with a blended approach of STEM, and in line with prepared lesson plans during the educational sessions. In these educations, it was mostly tried to provide the condition to blend the STEM branches via performing various projects relevant to real life. On the other hand, the control group was educated via Shad application in line with the experimental group but using a traditional and common approach. One more time the inventory of Heppner's problem-solving skills was distributed to the participants after finishing the educational sessions the scores were regarded as post-test evaluation. The post-test results were analyzed after entering SPSS.

Teaching Performance Method

Teaching was performed by using blended learning via a common approach and STEM approach. The theoretical topics of the study were examined before teaching performance. First, various models were investigated to implement blended learning. Considering the facilities and conditions in both schools, the rotation model was selected among the four models of learning introduced by Staker and Horn (rotation, Flex, self-blend, and enriched virtual). According to the students who are rotating in the class, between classes, or outside the class, the rotation model was called so and it is divided into four sub-models. These sub-models include the station rotation model, lab rotation model, flipped classroom model, and individual rotation model.

Because the selected schools were equipped with one data, the flipped classroom was selected among the four sub-models thus other models of blended learning that needed more computer systems could not be run. Moreover, the Shad application was the only platform from the perspective of the principals. Besides, the other rotation models need a lot of freedom of action in terms of time and space naturally which was not executable at schools. Because the educational period started after Nowruz'vacations (Persia new year celebration) and the ministry of education decided to continue the educational classes in person, the students severely decreased using Shad application by the principals' recommendations. In this situation, the researchers tried to run a part of teaching in the flipped classroom by delivering some parts of their activities and explanations to Shad application.

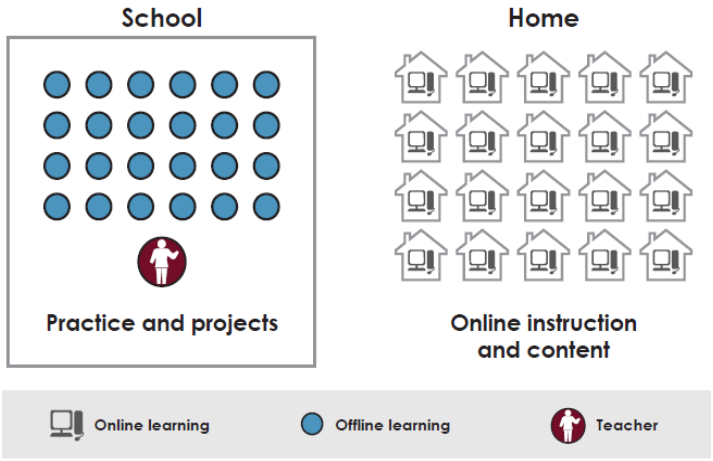

Fig 1. Flipped-Classroom model (Staker and Horn, 2012)

After that, the lesson plan procedure was started. The lesson plans were prepared using the traditional and teacher-centered approaches such as lecturing because the mental pattern and getting influenced by the STEM approach was not shaped at first. Then, the lesson plans were prepared via the STEM approach. No same method has been formulated for the STEM approach so far since there is a wide range of educational methods and running any method can be different due to the conditions of the school and learners (Williams, 2011). Therefore, for shaping the regarded form, the first researcher participated in a period with the title of "Integrated STEM Teaching for Secondary School Return" that was performed by the European Science Education Association from October 25 until December 1 in 2021 lasting 25 hours and received valid certification in this period. European Science Education Association professionally supports and promulgates STEM training. This association recommends a format to compile STEM training titles as "STEM in Integrated Learning Scenario" that the researcher has compiled the lesson plans based on the STEM approach. According to this association, only one method has not been selected, but various teaching methods, in each session appropriate to the students' proficiency levels and ability have been applied.

The procedure of teaching of the chapter "energy and its transformations" in the experimental group is presented. It has been tried to present a student project at the end of each chapter regarding very limited time. Shad application was used to have constructive conversations with the students, asking and answering, uploading exercises and receiving them, and uploading complementary explanations about activities and projects such as the expected projects and required facilities during the educational period. First, the teacher divided the students into four groups and these groupings were always used in activities and conversation performances. The students were remembered that no idea or suggestion is stupid and all opinions should be heard politely.

At the beginning of the first session and after creating a primary relationship, the brainstorming was started with some questions in the form of a word association game. The activity of pushing the chairs was done by the students to get familiar with the concepts of work, consuming energy, and their relationships after their participation. It should be noticed that effective conversations are highly emphasized in this approach; therefore, the course explanations were conducted in the forms of asking and answering to provide the appropriate condition for having a conversation and expressing ideas. After that, an activity combined with mathematics was done to calculate the energy in the learners' arms and its transformation. Therefore, the students faced a new concept called Power via numerous questions. In the last, the final evaluation was done along with investigating the course book.

In the second session, three different bodies were investigated to completely explain kinetic and potential energy and a conversation occurred with different examples in terms of the effects of these concepts on the engineers' jobs. A worksheet for the waterwheel project was given to each group after giving an explanation about waterwheels and the role of engineers in creating them. The students in each group as an engineering team were faced with an important challenge in this worksheet. The city authorities want to use hydro energy than coal to decrease the city's air pollution. An engineering design company is looking for the most efficient design for the waterwheel. The learners have been provided with the opportunity to write their designs on paper via consensus. The overall design was introduced by the teacher and the required equipment was prepared for implementing the waterwheel project by each group in the next session.

In session three, an opportunity was given to construct the project and then, the projects were experimented in the schoolyard. The plans were diagnosed with the learners' help during the experiment, and some recommendations were presented for promoting each of them. Moreover,

useful conversations were done in terms of characteristics of a good waterwheel and effective factors on the degree of done activity and its power. In the following, energy transformations were performed and the learners perceived these transformations more tangibly via Phet and ISLA simulations. In this regard, the role of engineering in more effective energy transformations during daily life and also, the STEM jobs such as bioenergy experts that are active in blended fields were discussed.

Fig 2. Examples of water wheels made by students

Findings of the Study

First, the data (that were collected via questionnaire in a case study) were extracted and entered SPSS-19 to be analyzed. The statistical indicators of each variable were calculated in investigating the descriptive data. The Kolmogorov-Smirnov test was used to investigate the variables' normality of distribution in the inferential statistics section, and an analysis of covariance was run to investigate the study hypotheses. The Kolmogorov-Smirnov test was used for the default test. The findings showed that the significant value for problem solving variable and its sub-scales are higher than 0.05. Therefore, it can be claimed with 95% certainty that all the variables follow the distribution of normality.

The Levene's Test was run to investigate the homogeneity of variance and regarding the data analysis, the equality of variance assumption was checked (P>0.05). Considering the sum of introduced assumptions, it is observed that the data can enter the Analysis of Covariance and the difference between the two groups can be investigated among the dependent variables. In the following, the researcher investigates the main assumption of the study via Analysis of Covariance. The main hypothesis is that "STEM-based teaching method has a significant influence on the students' problem-solving skill".

Table 1. The Covariance Analysis Findings in the Sub-scale of Problem-Solving Skill

Source	SS	Df	Ms	F	sig	Effect size
Pre-test	145.233	1	11.233	12.23	.030	.51
Group	149.426	1	149.426	27.21	.033	.161
Error	10523.821	67	157.072			

Total	1415065.000	70

Consulting Table 1, it is observed that there is a significant difference between the adjusted averages of problem-solving skill scores among the students in control and experimental groups ($P<0.05$). Therefore, it can be concluded that H0 is rejected and the STEM-based teaching method has a significant influence on the students' problem-solving skill and the degree of its practical significance has been 0.16. It means that 16% of the total variance of the students' problem-solving skills has changed based on the STEM-based teaching method.

Table 2. The Findings of Covariance Analysis in Problem-Solving Confidence

Source	SS	Df	Ms	F	sig	Effect size
Pre-test	4.673	1	4.673	.176	.046	.13
Group	40.861	1	40.861	11.541	.022	.225
Error	1776.322	67	26.512			
Total	168233.000	70				

According to the findings in Table 2, it can be concluded that there is a significant difference between the adjusted averages of sub-scale scores ($P<0.05$) among the students in control and experimental groups in the post-test phase for Problem-Solving Confidence sub-scale and removing the variable effect, regarding the calculated F factor. Therefore, it is concluded that H0 by which the STEM-based teaching method has not a significant influence on Problem-Solving Confidence has been rejected and the STEM-based teaching method significantly influences Problem-Solving Confidence sub-scale. The degree of practical significance for the sub-scale of Problem-Solving Confidence has been reported at 0.22. It means that 22% of the total variance of Problem-Solving Confidence sub-scale has changed based on the STEM-based teaching methods.

Table 3. Covariance Analysis in Approach-Avoidance Style Sub-scale

Source	SS	Df	Ms	F	sig	Effect size
Pre-test	122.951	1	122.951	2.474	.120	.036
Group	107.386	1	107.386	21.161	.046	.312
Error	3329.785	67	49.698			
Total	298770.000	70				

According to the findings in Table 3, it can be concluded that there is a significant difference between the adjusted averages of sub-scale scores ($P<0.05$) among the students in control and experimental groups in the post-test phase for Approach-Avoidance Style sub-scale and removing the variable effect, regarding the calculated F factor. Therefore, it is concluded that H0 by which the STEM-based teaching method has not a significant influence on Approach-Avoidance Style has been rejected and the STEM-based teaching method significantly influences Approach-

Avoidance Style sub-scale. The degree of practical significance for the sub-scale of Approach-Avoidance Style has been reported at 0.31. It means that 31% of the total variance of Approach-Avoidance Style sub-scale has changed based on the STEM-based teaching methods.

Table 4. Covariance Analysis in the Personal Control Sub-scale

Source	SS	Df	Ms	F	sig	Effect size
Pre-test	152.547	1	152.547	5.891	.018	.081
Group	13.224	1	13.224	14.511	.025	.276
Error	1735.087	67	25.897			
Total	22985.000	70				

According to the findings in Table 4, it can be concluded that there is a significant difference between the adjusted averages of sub-scale scores ($P<0.05$) among the students in control and experimental groups in the post-test phase for Personal Control sub-scale and removing the variable effect, regarding the calculated F factor. Therefore, it is concluded that H0 by which the STEM-based teaching method has not a significant influence on Personal Control has been rejected and the STEM-based teaching method significantly influences Personal Control sub-scale. The degree of practical significance for the sub-scale of Personal Control has been reported at 0.27. It means that 27% of the total variance of Personal Control sub-scale has changed based on the STEM-based teaching methods.

Discussion and Conclusion

The overall purpose of this study was to investigate the impact of STEM-based blended science education on the students' problem-solving skills. The main hypothesis was based on the claim that the STEM-based teaching method influences the students' problem-solving skills significantly and positively. The results of the data analysis revealed that the problem-solving skills of the students who received STEM-based education were significantly different from the students' skills who received common education ($P=0.05$). Therefore, it can be concluded that STEM-based science education has had more influence on the students' problem-solving skills and this effect has been statistically significant. Thus, the main hypothesis of the study is confirmed. Moreover, according to the findings and the analysis of Covariance, it can be claimed that STEM-based education has a significant and positive influence on the three problem-solving sub-scale of Problem-Solving Confidence, Approach-Avoidance Style, and Personal Control.

These findings are congruent with Serin (2009), Yuliati (2020), and Sahin (2021) in terms of education methods and approach impact on promoting the students' problem-solving skills actively and confirm their findings. These studies show that the appropriate educational approaches cause more interaction among the students and provide opportunities for them to face real-world situations. The students can experiment, analyze, and conclude their issues via conversation and research that promote their problem-solving skills. Further, this approach strengthens the interaction and teamwork skills among the students.

Since the development of problem-solving skills is not only important in the new generation standards of science education and international exams, but it is more important than ever for encountering the changing world, promoting this skill is highly significant as the main priority of science education. Thus, the blended approach STEM can be used to increase educational procedure efficiency and promotes the students' and teachers' performance in the procedure changes and education approach to science courses in the future.

Not ideal samples due to the researcher's job limitation were an effective factor in this study. Moreover, severe weakness of the students' language and literature skills as the result of inefficient virtual education caused more difficult and time-consuming conditions for interaction and following up the scientific discussion than expected. It is recommended to conduct a study of

the impact of STEM-based education on other cognitive skills in schools regarding this study's findings. Further, the impact of this approach on the teachers' teaching skills should be studied.

Acknowledgement
This work was supported by Shahid Rajaee Teacher Training University under grant number 5025.

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