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Student Career Interest in Science: A Study of STEM-Based Learning on Buffer Topic

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Abstract

The modern era is currently highly dependent on technology in almost all aspects, so the demand for experts in the field of technology is increasing. However, this does not match the situation in schools. Therefore, countries in the world are starting to implement the STEM approach to the national curriculum. This study aims to determine the increased interest in a career in science for students after applying the STEM approach. This research is a quasi-experimental using pretest-post-test control group design. The instrument used scientific career interest questionnaire that refers to the Social Cognitive Career Theory. The results show that the application of STEM through STEM activities such as formulating problems, designing solutions, practicums, and planning projects, will provide knowledge about students' career interests. The increase in students' career interest in science in the material on buffer solutions shows significant results. Environmental aspects more dominantly influence students' career interests with the dominant indicator being school teaching staff. Further research can be carried out to see the increase in students' interest in careers in science after implementing a STEM approach at a larger sample level such as a sample of high school students in a city.

Keywords: buffer solution, career interest, chemistry education, STEM

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1. Introduction

In today's modern era, all global aspects are highly dependent on science and technology, which has an impact on the demands of students to have the competence and expertise to overcome various real-world problems from a scientific and technological perspective (Chapman & Rebecca, 2017; National Science & Technology Council, 2018). This also has an impact on students' perspectives on how they learn, communicate and interact in order to adapt and succeed globally (Fitriyana et al., 2024). Therefore, global education also begins to focus on learning that can produce students who are globally competitive in the 21st century. This 21st century global competitiveness focuses students on understanding Science, Technology, Engineering, and Mathematics (STEM) directly.

The presence of the STEM (Science, Technology, Engineering, and Mathematics) approach is considered very important as an effort to reform education towards successful global adaptation in the future (Bullock, 2017; Tan, 2018).

In addition, the STEM approach is also considered to be able to develop analytical thinking skills and attitudes towards science learning Chonkaew et al., (2016), critical thinking skills Sanders, (2008), increase interest in learning and enthusiasm for pursuing a career in STEM fields (Chachashvili-Bolotin et al., 2016; Franz-Odendaal et al., 2016; Jones et al., 2019; Miller et al., 2018; Mohd Shahali et al., 2019) and provide more experience as a basis for the lifelong learning process (Fitriyana et al., 2021). Therefore, countries around the world are starting to implement the STEM approach in their national learning curriculum.

However, this is not in accordance with the situation at school. Some students experience a decrease in interest in learning and careers in science. This decrease in interest and motivation is caused by several factors such as internal factors such as level of interest, interest and motivation, cognitive level, gender differences and external factors such as environmental factors both in terms of family characteristics, socio-economic status, culture, to school facilities and infrastructure (Reinhold et al., 2018). Based on the case of declining student interest in the field of science, this is also the basis for countries in the world to start implementing the STEM approach in the national learning curriculum.

The STEM approach is an approach to education that integrates four disciplines, which are science, technology, engineering and mathematics, with a focus on problem solving in everyday life and professional fields, critical thinking skills, creativity and teamwork as well as communication as a pedagogical strategy (Shahali et al., 2015). This STEM approach is implemented by inviting students to understand more deeply about science and chemical concepts in an abstract way Lewis, (2006) through teaching in applied environments such as technology Petritis et al., (2021) and technic (example: developing models, designing products) Lewis, (2006) and application of techniques to solve problems related to the world of work Aydin-Gunbatar et al., (2018) and implementing problem-based learning Carlisle & Weaver, (2018) to be able to grow critical thinking construction Huri & Karpudewan, (2019), and provide meaningful learning for students (Petritis et al., 2021).

One example of material that can be further developed is buffer solutions. This is because students still experience many difficulties in understanding buffer solutions, one of which is connecting macroscopic and microscopic aspects in buffer solutions. This is also exacerbated by some students who do not yet understand the benefits of knowledge and the importance of this material for the next level of chemistry. If students have implemented learning activities using STEM education, it is hoped that they will be able to generate their own unique and original scientific ideas, which will then create a sense of challenge in the buffer solution material as it is being studied in students. Furthermore, the role of educators here can help students to direct their interests and motivations in chemistry by providing input, support, and career counseling regarding the benefits of chemistry in the world of work and regarding further studies related to science that will be planned by students. In previous research Avargil et al., (2020) concludes that educators need to provide positive knowledge and expectations to students regarding career orientation, career guidance, career preparation, and career information in the STEM field.

A person's career interest in science can be seen and explained through the career interest instrument in Social Cognitive Career Theory (SCCT). Social Cognitive Career Theory (SCCT) explains that a person's career interest in science can be seen through personal and external aspects. In the personal aspect, it is influenced by indicators that emphasize self-efficacy or a person's belief in their abilities, hopes and goals. This aspect looks at how a person views their self-confidence regarding their abilities in science, both in terms of understanding, problem solving, and having a career in science. In terms of the environment, a person's career interest can be influenced by family or friends, school teachers and awards/status/prestige. In the family or friend environment, it can have a significant influence on a person's views in choosing a career in the future. School teachers can also influence a person's career interest through the learning experiences provided at school. The influence of awards/status/prestige is usually influenced by the views of society regarding the chosen career field. The chosen career will usually be associated with economic/financial factors by society who look down on the career chosen by a person (Avargil et al., 2020). Research conducted by Jones et al., (2019) which discusses the freedom to choose science learning and career choices in STEM, says that people who have more interest in STEM tend to choose a career in STEM and are not influenced by the surrounding environment such as friends' perceptions, teachers' perceptions and parents. People who have an interest in this study believe that starting from being interested in STEM subjects will form the belief that STEM subjects are important for their future success.

Based on the description above, the research question can be written as "How to increase students' career interest in STEM-based learning?" So, the purpose of the study is to determine the increase in career interest in science in students after implementing the STEM approach.

2. Research Method

This research was aims to see whether there is an increase in students' career interest in science in the buffer solution material by applying the STEM approach. Research methods such as research type and design, participants and research context, data collection techniques and instruments, and data analysis are briefly explained in this section.

This research was carried out using a quasi-experimental method with a pretest-posttest control group design using two groups, which are the experimental group and the control group. The two groups were given different learning treatments. In the experimental group, learning will be carried out using the STEM approach and the control group will use a scientific approach. The STEM approach is implemented through STEM activities, such as designing laboratory equipment, designing laboratory materials, formulating problems, designing problem solutions, designing work methods, implementing and writing laboratory data, planning projects, calculating buffer pH values, and answering questions. The experimental and control groups will also be carried out pretest-posttest at the beginning and end of learning by using a career interest questionnaire in science.

The population in this study was all eleventh-grade students majoring in Mathematics and Natural Sciences at a public high school in Kulon Progo Regency. The sample was taken from 62 eleventh-grade students majoring in Mathematics and Natural Sciences at SMAN 1 Sentolo.

The research data was obtained from a career interest questionnaire score in science. The scientific career interest questionnaire used refers to the Social Cognitive Career Theory (SCCT) (Hackett & Byars, 1996). Social Cognitive Career Theory (SCCT) explains that one's career interest in science can be seen through personal and external aspects. Based on these two aspects then developed further divided into 6 indicators which are self-confidence, self-confidence in being able to learn science, self-confidence in being able to have a career in science, family and friends, influence from school educators or famous figures, financial motivation, social status.

Based on these 6 indicators, 58 statement items were produced which were used to see overall how students' career interests in the field of science were before and after the implementation of learning with a STEM approach in the experimental group and a scientific approach in the control group. The career interest questionnaire grid used in this study can be seen in Table 1.

Table 1. Final Version of Questionnaire

Factor	Indicator	Statement	Item Number
Personal	Self-efficacy-scientific learning	I can complete assignments on time	1-11
	Self-efficacy-task oriented	I can understand scientific articles	12-24
	Self-efficacy-confidence in one's career in science	Choosing a career related to science was a difficult choice for me	25-35
Environment	Family and friends	I am interested in a job that will increase the social status of the family	36-44
	Influence from my teacher or famous figures	My teachers motivated me to study chemistry more deeply because of the career path I chose	45-49
	Financial motivation and social status	Jobs in science are jobs that make a lot of money easily	50-58

The instrument was validated theoretically by expert judgment and empirically before being used in the study. Theoretical validity demonstrated improvements in the use of conjunctions, standard punctuation, and appropriate sentence coherence. Empirical validity revealed two invalid items out of a total of 60 statements. Therefore, the total number of statements usable for this study was 58. The results of the reliability test were carried out using the Cronbach's Alpha equation and obtained a Cronbach's Alpha coefficient of 0.918 which is in the very high category.

The resulting data consisted of total scores from the student career interest questionnaire in science at the beginning and end of the study. These were then further analyzed using the Wilcoxon Signed-Rank test to determine whether there was a significant increase in career interest in science in each group. Furthermore, to compare the level of increase in student career interest in science between the two groups, the Mann–Whitney U test was used.

3. Result and Discussion

This research was conducted to determine whether there was an increase in students' career interest in science by applying learning using the STEM approach to buffer solution material. This research was carried out in two groups that were given different treatment, which are in the experimental group applying learning with the STEM approach and the control group applying learning with the scientific approach. The results obtained from the research will be discussed in more depth in the following discussion.

Table 2. Descriptive Statistics

	N	Mean	Std. Dev	Min	Max
Pre Test Exp	31	206.41	15.56	175.00	239.00
Post Test Exp	31	226.22	16.02	199.00	257.00

Based on the results of the Wilcoxon Signed-Rank test in the experimental class, in Table 2, the average career interest score of students in the experimental class increased after participating in STEM-based learning. The average difference between the pretest and posttest was 19.81 points, indicating a significant increase.

Table 3. Wilcoxon Signed-Rank

		N	Mean Rank	Sum of Ranks
Pre Test Exp	Negative Ranks	5[a]	3.90	19.50
Post Test Exp	Positive Ranks	26[b]	18.33	476.50

Table 3 shows that 26 students experienced an increase in their career interest scores after STEM-based learning and only 5 students experienced a decrease. The mean rank value indicates a strong upward trend.

Table 4. Test Statistics

	Post_Eksperiment_Career Interest - Pre_Eksperiment_ Career Interest
Z	-4,479[b]
Asymp. Sig. (2-tailed)	.000

Table 4 shows that there was a significant difference between the pretest and posttest scores of students' career interest in the experimental class. The effect size calculation produced a value of r = 0.80 which is included in the large category, indicating that STEM-based learning has a strong influence on increasing students' career interest. Thus, STEM-based learning significantly increases students' career interest in the material of buffer solutions.

Table 5. Descriptive Statistics

	N	Mean	Std. Dev	Min	Max
PreTest Con	31	198.93	15.43	165.00	229.00
Post Test Con	31	203.25	16.10	172.00	231.00

Based on the results of the Wilcoxon Signed-Rank test in the control class, in Table 5, the average career interest score of students in the control class increased slightly, with a difference of 4.32 points, which shows that this increase is smaller than the experimental class.

Table 6. Wilcoxon Signed-Rank

		N	Mean Rank	Sum of Ranks
PreTest Con	Negative Ranks	11[a]	12.91	142.00
PostTest Con	Positive Ranks	17[b]	15.53	264.00
	Ties	3[c]		

In Table 6, it shows that 17 students experienced an increase in career interest scores, 11 students experienced a decrease and 3 students did not change. The mean rank value shows a slightly higher increase than the decrease, meaning the increasing trend is not too strong.

Table 7. Test Statistics

	Post_Control_ Career Interest - Pre_Control_ Career Interest
Z	-1,390[b]
Asymp. Sig. (2-tailed)	.165

In Table 7, it shows that there is no significant difference between the pretest and posttest scores of students' career interest in the control class. The calculation of the effect size produces a value of r = 0.25 indicating that scientific approach learning only has a small effect on students' career interest. Therefore, it can be concluded that STEM-based learning is more effective than scientific approach learning in increasing students' career interest in the material of buffer solutions.

Table 8. Test Mann–Whitney

	Score
Mann-Whitney U	238.500
Wilcoxon W	734.500
Z	-3.409
Asymp. Sig. (2-tailed)	.001

Based on the Mann–Whitney test results in Table 8, the Asymp. Sig. (2-tailed) value for students' career interest increases was 0.001 ($p < 0.05$). This indicates a significant difference between the experimental and control classes. Thus, STEM-based learning is significantly more effective in increasing students' career interest in buffer solutions than scientific approach learning.

When learning using the STEM approach takes place, there are 9 STEM activities consisting of designing lab tools, designing lab materials, formulating problems, designing problem solutions, creating work method designs, implementing and writing lab data, planning projects, calculating buffer pH values, and answering questions. All of these activities are fully visible on the student worksheet provided. The lesson begins with an illustration of a beverage entrepreneur producing a drink that provides a refreshing taste with a bubbling sensation when consumed (a soft drink). The teacher encourages students to critique the soft drink by asking questions about the taste of the soft drink that differ from the four basic tastes perceived by the tongue (sweet, sour, bitter, salty). The teacher begins to direct students to investigate by asking initial questions such as "are soft drinks related to buffer solutions?", "how can we prove that soft drinks or other products contain buffering properties?". Next, students discuss designing an experimental method to prove whether soft drinks or other products contain buffering properties or not and discuss the tools and materials needed. Students are asked to design solutions that can be used to answer the problems found. Students discuss their solution designs with the teacher, and the teacher provides input and direction related to laboratory skills such as using pipettes, measuring pH, reading scales, using test tubes, and others. In the activities carried out by students, it can be seen how students criticize the situation of the problem they are facing and analyze various possible solutions that can be used.

In the first discussion, students discuss with each other to design a simple practicum that is used to answer the existing problem, both from the design of the tools needed, the materials used, the required sample volume to be used to the work method to be implemented. Then on the next day, students change their design again on a new sheet, and it can be seen from the results of the revised practicum design that students become more careful about the steps to be carried out in the practicum and become more curious about things that they find interesting and new. This is in accordance with research conducted by Chonkaew et al., (2016) that the thinking process in planning an activity trains students to integrate and apply conceptual and procedural knowledge with the context of the problem faced so that students become more able to create enjoyment and learning activities and produce impacts in accordance with predetermined goals.

Next, together with their group members, students conduct simple experiments to prove and find answers to existing problems. The experiments are conducted using materials available around the students and tools and materials already available in the school laboratory. Next, students will discuss the results of the experiments obtained by connecting the data obtained with existing theoretical sources and students will present their experimental results. Based on the results of the practicum carried out and presented, there were several groups that did not obtain appropriate data results. This makes for interesting and good material for questions in the presentation's question and answer session. In the QnA session, one group gave a critical answer to the data obtained, "Yes, in the research we conducted, the practicum data obtained did not match the theory in the book. The results of our practicum used a sample of eye drop solution, where the data obtained showed a significant change in pH before and after adding HCl and NaOH. This does not match the existing theory, because the volume designed in our group's work method design was too much so that it was not comparable to the volume of eye drops used. If the volume of NaOH and HCl used was reduced by a few drops as done by group 3, the results would be in accordance with the theory, such as the practicum results presented by group 3 and other groups." Based on these answers, students were able to critically show the cause and effect and reasons for a phenomenon that occurred. They explained how this could happen, the impacts that occurred, and solutions that could be used. This kind of perspective is what is expected from learning using the STEM approach. This is in accordance with research conducted by Huri & Karpudewan, (2019) that meaningful learning will make students more interested so that they become more willing to be involved and think further and repeatedly about the activities to be carried out. In this section, students will be involved in further discussions, will learn from failures and decide on the choices to be chosen and will review their activities until the problem is solved. In addition, this is also in line with research conducted Chonkaew et al., (2016) the process of planning before acting is a critical stage where students can use scientific methods in creating a design efficiently that can train various thinking skills. This activity shows a high quality of learning interest because it requires students to reflect and connect observations to real-world applications. Therefore, this demanding activity indirectly builds their thinking construction.

When learning using the STEM approach takes place, all student activities are linked directly and indirectly to careers in science, such as scientists, quality control experts, pharmaceutical products, beverage entrepreneurs, and researchers. For example, in learning activities, students are guided to think from the perspective of a soda producer, enabling them to analyze the relationship between production processes, material efficiency, and environmental responsibility. Students are trained in representational skills by transforming soda production problems into flow diagrams, chemical equations, and narrative explanations. Students are guided to become someone who has a career in science so they can see a different perspective if they pursue a career in science. This is demonstrated when students carry out project planning activities, where students are taken to the perspective of a scientist expert in the pharmaceutical product industry who is developing their product. This product will later be mass-produced by the company as one of the company's main products. In the product manufacturing process, you need to consider several aspects such as raw materials, equipment availability, product quality testing, consumer response, marketing prospects, and product packaging. In the product packaging aspect, you are asked to plan how to package the product well and meet the standards required by consumers.

Next, students are asked to express all their design plans, ideas, and creativity to solve the problems developed. This activity shows a positive impact, as students become more sensitive to what certain careers involve. Students become more open and critical, especially regarding things that need to be considered in producing a product to ensure the quality and benefits of the product are not damaged until it reaches the hands of consumers. In this activity, students ask more questions and debate among groups regarding the right decision in determining one aspect such as determining product packaging materials. To connect existing topics with several aspects of career interests and also university education levels. This is in accordance with research conducted by Blotnicky that learning by providing teamwork experiences, problem solving and cross-disciplinary applications and creativity provides broader knowledge about specific science careers and how to pursue those science careers which are then used as motivators for students to choose a career in science (Blotnicky et al., 2018). This is also in accordance with research conducted by Dabney that school factors such as special classes, extracurricular activities, science fairs, to initial perceptions about mathematics and science can also influence students' future career and study choices (Dabney et al., 2012).

In this study, the experimental group that implemented learning using STEM showed a significant increase where 26 students experienced an increase in career interest scores after STEM-based learning and only 5 students experienced a decrease. This is also supported by the results of a strong upward trend where there was a significant difference between the pretest and posttest scores of students' career interest in the experimental class. Therefore, STEM-based learning has a strong influence on increasing students' career interest in the material of buffer solutions.

This is because, after the learning process, students' insights and perspectives on career paths and future prospects became more open to various science-related career options and future prospects, and they demonstrated interest in pursuing a career in science. This was evident in the discussion session, where, during the discussion of the project planning assignment, students were provoked to discuss careers based on the introductory sentence about project planning. These activities and responses are expected from STEM-based learning, where STEM activities are expected to stimulate students' curiosity and interest in several science-related careers. This aligns with previous research that found that STEM learning experiences increase students' knowledge of several STEM-related careers (Mohd Shahali et al., 2019).

In the control group, students' career interest increased in the low category. This is influenced by several reasons, including the lack of self-confidence of students in their abilities. Most of the students felt insecure about having a career in science because their skills were not very good in science, they felt that science was difficult to learn, so that some participants complained that there was a mismatch in career choices with their parents "I am interested in studying informatics engineering, because at first I was interested in coding and computers, but my parents didn't agree, and thought I just wanted to play games every day." To other students, they said, "I want to enter law, but my parents don't allow and force me to enter science so I can become a midwife." because my parents and siblings already have a clinic and want me to continue. But myself realized that I am not very good at science." Based on direct opinions and questionnaires, it can be seen that environmental factors influence students in deciding careers in science so that many students experience indecision in choosing. This is in accordance with research conducted by Avargil et al., (2020) that environmental aspects can influence students' career interests.

In the Career Interest Questionnaire in the field of science, there are 6 indicators analyzed in this study, which are indicators of self-confidence in learning science/chemistry, task-oriented self-confidence, career self-confidence in science, awards/status/prestige, school educators, and families/friends. The results of the analysis for each indicator can be seen in Figure 1.

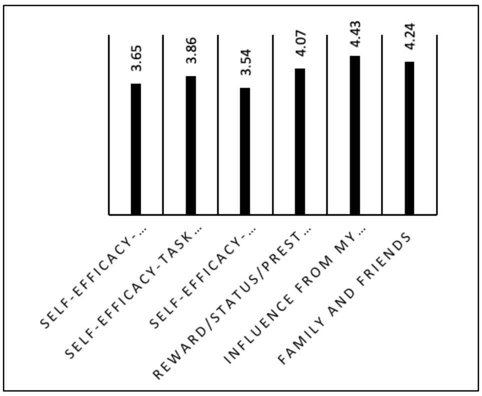

Figure 1. Results of Analysis of Indicators of Career Interest in Science

Based on the results of the analysis of indicators of career interest in science in Figure 1, it can be seen that the dominant aspect, which one the environmental aspect with the highest achievement, was in the indicators of school teaching staff, then leaving/friends, and awards/status/prestige. Meanwhile, on the personal aspect, the dominant indicator is self-confidence-task-oriented, then self-confidence-learning science/chemistry, and finally self-confidence-a career in science.

Based on the results of the analysis on a career interest questionnaire in science, the highest average aspects obtained by students were aspects of school educators, family/friends and awards/status/prestige. This is in accordance with previous research which states that students' career interests are strongly influenced by the environment, in this case, which are family/friends and school educators (Avargil et al., 2020). This is also in line with research conducted by another reference which state that educators have a more positive impact by supporting and encouraging students to continue STEM to a professional level, in this case, the career path (Reinhold et al., 2018). In another paper, parents' expectations have more influence in determining the choice of college. This proves that the influence of environmental aspects has more impact on career interests in science for students who carry out learning by implementing STEM activities (Sellami et al., 2023).

4. Conclusion

The results of this study demonstrate that the implementation of STEM-based learning significantly enhances students' career interest in science on the topic of buffer solutions. STEM activities, such as problem formulation, solution design, laboratory experimentation, and project planning, provide meaningful learning experiences that expose students to science-related careers. The findings reveal that students in the experimental group showed a substantial increase in career interest compared to those in the control group. Environmental factors were found to have a dominant influence on students' career interest, particularly the role of school teachers. These results indicate that STEM-based learning not only strengthens conceptual understanding but also plays an important role in shaping students' career aspirations in science. Therefore, the integration of STEM approaches in chemistry learning is strongly recommended to support students' future career development in science-related fields.

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