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CRTP: learning model for integrating STEM competencies in pre-service biology teachers

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ABSTRACT

The development of education shows the importance of integrating science, technology, engineering, and mathematics (STEM) in schools and preparing teachers who are ready to implement STEM in the classroom. This study aims to describe prospective teachers' perceptions of STEM competencies through the collaborative reflective teaching practice (CRTP) model in micro teaching courses. The method used was qualitative using interview assessment and questionnaire of STEM perception. This study used an experimental design conducted with 3 activities (initial test, teaching practice, and final test). The initial test and final test used a STEM perception questionnaire. Teaching practice in the form of applying the CRTP model which consists of 4 stages, namely plan, simulation, implementation, and reflection. The results of the study describe that STEM competencies develop well with the CRTP model. The questionnaire results showed that 96.2% of respondents strongly agreed that the CRTP model had proven valid for developing STEM competencies of prospective biology teachers. This research contributes to educators who prioritize meaningful learning experiences for prospective biology teachers. The authors suggest that effective STEM competencies should incorporate five main components: i) reflection, ii) collaboration, iii) integration of interdependent STEM disciplines, iv) skills related to STEM disciplines, and v) integrative STEM teaching and learning.

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1. INTRODUCTION

Science, technology, engineering, and mathematics (STEM) competencies have become a hot topic among education experts [1]. The initial idea of STEM competencies emerged in America in the 1990s. Until now, many countries (both developed and developing countries) are promoting STEM competencies in their education system [2] such as in Saudi Arabia, South Korea, Thailand, and other countries [1]–[3]. Australia has the Australian Schools STEM Education Strategy 2016-2026. Malaysia has been implementing STEM in schools since 2017 [4]. Indonesia is implementing Merdeka curriculum that emphasizes 21st century education, the application of reflective, collaborative principles, and STEM competencies since 2020 [3], [5], [6].

The Indonesian government launched various trainings to improve STEM competencies such as project-based learning, problem-based learning, and discovery learning model trainings [4], [7]. Previous

research has explored the impact of various models (project-based learning, problem-based learning, and discovery learning) in teacher professional development [8]–[10], but have not explicitly discussed the effect on STEM competencies. This study investigates the effects of learning models on STEM competencies of prospective biology teachers that have never been reported before. New learning models that are valid, practical, and effective in accommodating STEM competencies comprehensively are needed. STEM competencies comprehensively include the ability to make decisions, socialize, collaborate, reflect, and care about local and global environmental issues [10], [11]. Researchers introduced the collaborative reflective teaching practice (CRTP) model which is believed to be able to accommodate STEM competencies comprehensively. The CRTP model is built from the adaptation of reflective teaching and collaborative learning methods. The CRTP model syntax construction chart is presented in Figure 1.

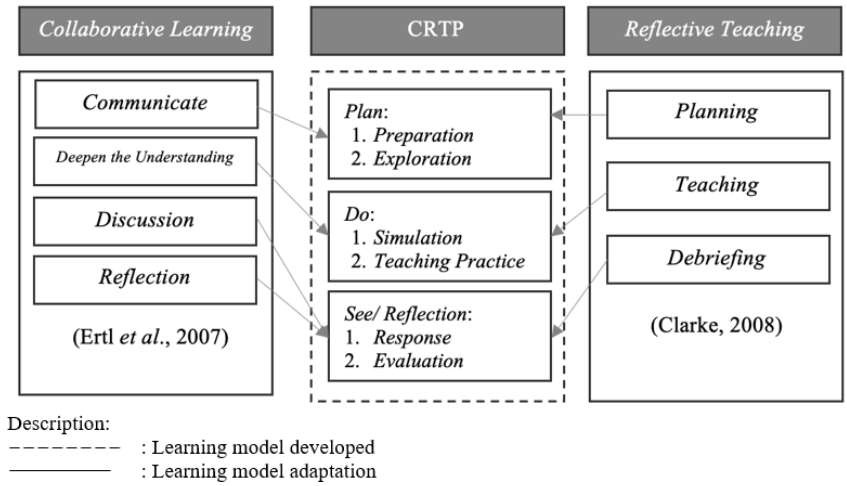

Figure 1. CRTP model syntax construction

Since 2007, the collaborative learning model has become one of the models that can develop communication skills and foster a culture of reflection [12], [13]. Along with the development of science, educators are not only required to be able to communicate, but also to be able to design and explore the latest information with a multidisciplinary approach [14]. We found that the communicate stage in the collaborative learning model correlates with the plan stage in the CRTP model we developed (Figure 1). The plan stage in the CRTP model proposed in this study tends to provide meaningful space for prospective biology teachers to develop STEM competencies. The CRTP model has a more comprehensive plan stage, namely preparation and exploration. Complex stages are the advantages of the CRTP model when compared to previous models, namely collaborative learning and reflective teaching models (Figure 1). In other words, the proposed CRTP learning model has the potential to improve the STEM competencies needed by biology teachers in the 21st century [15], [16].

2. METHOD

This research methodology uses an interpretive paradigm and a qualitative approach in a micro teaching course at one of the Lembaga Pendidikan Tenaga Kependidikan (LPTK) or educational personnel education institutions in Indonesia. The pre-service teachers designed, developed and taught STEM-based teaching with the CRTP model in their teaching practice. This research prepares biology teacher candidates to be able to design and implement lessons using the CRTP model. We were interested in exploring prospective biology teachers' perceptions of the integration of STEM competencies in micro teaching courses. A total of 52 biology teacher candidates for the 2022/2023 academic year were involved and introduced to the CRTP model for developing STEM competencies and integrating STEM competencies with a multidisciplinary approach. For five weeks, the prospective biology teachers have been able to design lesson plans using the STEM approach. The lecturers involved consist of 3 lecturers who teach basic teaching skills and micro teaching courses which are determined by convenience sampling. Each lecturer in one learning community will assist 6 to 7 prospective teachers. The teachers involved are 9 biology teachers from partner schools where the prospective teachers carry out field experience practices. The instrument used in this study was a questionnaire on the responses of prospective biology teachers about the perception of STEM [17]. The

perception of biology teacher candidates about STEM integrated in the CRTP model was obtained from the six statements below:

- The right approach to integrating STEM

Prospective biology teachers' views on appropriate approaches to integrating STEM were explored using three options. The three options were based on the approaches proposed by previous studies [18]. The three approaches are silo, embedded, and integrated (Figure 2). According to the silo approach, science, technology, engineering and math are separate fields. In the embedded approach, one content is given priority over the others while in the integrated approach, it is known that materials from several STEM domains are taught together. The three approaches are illustrated in Figure 2.

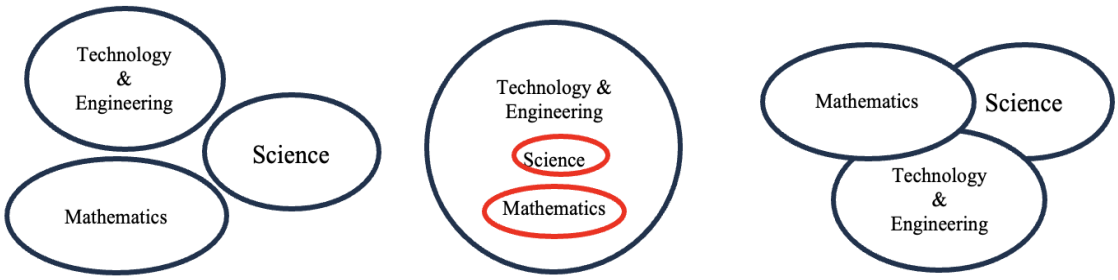

Figure 2. Three approaches to integrating STEM competencies [17]

- Perception of biology teacher candidates in integrating STEM competencies

Preservice biology teachers' perceptions of STEM competencies integrated in the CRTP model, were explored using the following six statements [17]: i) STEM competencies can be integrated with the CRTP model, ii) the CRTP model can be used to train prospective biology teachers in STEM skills, especially in reflection, iii) implementation of the CRTP model can teach prospective biology teachers STEM skills, especially in collaboration, iv) STEM competencies of prospective biology teachers trained with the CRTP model are able to integrate interdependent multidiscipline, v) prospective biology teachers need to integrate STEM competencies in instructional design, and vi) STEM competencies can be applied contextually in CRTP.

- Challenges in integrating STEM competencies

The third question in the questionnaire will ask about prospective biology teachers' thoughts on difficulties in adopting STEM skills. Participants were given a list of possible answers, and they were allowed to select more than one answer. The final question from the researcher asked prospective biology teachers' opinions on whether Indonesia is a good candidate for incorporating STEM competencies into the biology curriculum in schools?

3. RESULTS AND DISCUSSION

3.1. Biology teacher candidates' perceptions of the STEM integration approach

Only 3.8% of biology teacher candidates used the silo technique when planning and implementing lessons. This indicates that prospective biology educators do not widely accept silos. Segregated learning of STEM subjects is a hallmark of the silo method, with teacher management of instruction dominating. Teachers teach what needs to be known with the aim of developing information that leads to assessment, therefore, students rarely get the opportunity to explore knowledge on their own [12], [17], [18]. The integrated method is preferred by 73.1% of preservice biology teachers -38 in total - in the process of planning and implementing their teaching. Since they believe that the silo approach lacks integration between subjects, based on the interview results, they tend to prefer the integrated approach over the silo approach. Therefore, it may be difficult for students to understand how STEM disciplines are applied to real-world problems. By identifying a common problem and applying critical thinking, problem solving, and knowledge to reach a conclusion about a solution, the integrated method combines topics from many STEM subjects [19]. The embedded approach was preferred by the 12 pre-service biology teachers as they found it to be very successful in enhancing teaching through understanding and application by tying in core subjects and embedded resources. Some materials are given higher priority in the embedded method, while others are integrated into it. For example, if a pre-service teacher incorporates engineering into a lecture on the digestive system by creating illustrations, the evaluation will prioritize material related to the digestive system.

3.2. Perceptions of preservice biology teachers who integrate STEM competencies

Findings from the investigation into how pre-service biology teachers perceive the CRTP model integrated with STEM skills are shown in Table 1. Based on the results of the analysis of the perceptions of prospective biology teachers shown in Table 1, it is obtained that they agree that the CRTP model is able to improve STEM competencies. They also think that STEM competencies are important to master in the current era of digital education. All prospective biology teachers also agreed (57.7%) if they obtained multidisciplinary material. Based on the perceptions of prospective teachers, information was also obtained that multidisciplinary material would foster the ability of prospective teachers to change perspectives involving at least two academic disciplines to solve a particular problem contextually (96.2%). In a complex and connected modern era, multidisciplinary knowledge is becoming increasingly important. Advances in various fields of science and technology have resulted in interconnections between different disciplines, requiring a holistic approach and broad understanding. Multidisciplinary knowledge influences biology teacher candidates to generate innovation, address complex problems, develop creativity, encourage collaboration, and support evidence-based decision-making. Therefore, prospective biology teachers need to utilize multidisciplinary knowledge because it has a better chance of achieving progress and success in self-development when becoming a teacher.

Table 1. Biology teacher candidates' perceptions of the CRTP model integrated with STEM competencies

No.	Statement	Percentage (%)			
		Strongly disagree	Disagree	Agreed	Strongly agree
1	STEM competencies can be integrated in the CRTP model	0	0	3.8	96.2
2	The application of the CRTP model can train the STEM competencies of prospective biology teachers, especially in reflecting on the STEM competencies of biology teachers.	0	0	71.2	28.8
3	The application of the CRTP model can train prospective biology teachers' STEM competencies, especially in collaborating with others.	0	0	65.4	34.6
4	STEM competencies of prospective biology teachers trained in the CRTP model are able to integrate science in a multidisciplinary and interdependent manner.	0	0	57.7	42.3
5	Pre-service biology teachers need to integrate STEM competencies in instructional design	0	13.4	48.1	38.5
6	STEM competencies can be contextually applied in the CRTP model	0	0	96.2	3.8

We found that 3.8% of respondents strongly agreed that STEM competencies can be integrated into the CRTP model. This assertion is rooted in teachers' perceptions that future educators should develop STEM competencies in micro teaching. This perception highlights several key aspects: the utilization of STEM education with a student-centered approach, the development of 4C skills, the development of a scientific mindset, the suitability of the CRTP learning model for integrating STEM competencies, and the relevance of CRTP as a valid, practical, and effective model in introducing STEM competencies to prospective biology teachers. Based on the perceptions of prospective biology teachers, the CRTP learning model proposed in this study can be stated as a pioneer and has a much higher level of validity in developing STEM competencies. This perception of prospective teachers is in accordance with previous research which reports that STEM competencies are able to improve teacher professionalism and lead to the ability to make decisions, socialize, collaborate, reflect, and care about local and global environmental issues [4], [7]. Through STEM, prospective teachers can communicate well in various situations. When prospective teachers have STEM competencies, prospective teachers will naturally have social interactions with their friends. Frequently inviting communication has a positive impact on developing communication skills among prospective teachers. This will stimulate the brain to model the use of good sentences. Through STEM, prospective teachers are trained to explain and exchange information with their friends during the learning process, learning how to convey information correctly, so that their friends can understand and comprehend it. STEM is really needed in developing 21st century skills so that it can foster and improve cooperation in a group to solve certain problems, increase tolerance towards differences in opinions of friends, try to think critically and creatively to solve problems about connecting things [10], [11], [20].

Some of the principles of the CRTP model use a student-centered approach, making it easier for prospective biology teachers to confirm the CRTP model [11], [21]. The CRTP model is able to accommodate and explore further creativity and critical thinking about the competence of prospective biology teachers in developing the creative thinking skills and enthusiasm of prospective teachers in designing lessons to overcome environmental challenges or problems [12], [16], [22], [23]. Another principle that needs to be mastered by prospective biology teachers is collaboration in designing lessons so that there is a connection and integration between competencies and/or content. A total of 65.4% of pre-service teachers said that using the CRTP model

can help them develop STEM skills, especially teamwork. The CRTP approach incorporates reflective and collaborative ideas. The majority of pre-service teachers (71.2%) believed that applying the CRTP model could help them develop STEM competencies, especially in reflecting. The objectives of the micro teaching course, which include the development of basic teaching skills and mastery of technology and content in various cross-knowledge domains, are aligned with the implementation of STEM-based learning [24], [25]. Collaborative and reflective concepts need to be mastered by preservice teachers so that STEM competencies can be ideally applied in designing and implementing learning [20], [26].

3.3. Challenges in integrating STEM competencies in probationary biology teachers

In this final section, the data we obtained relating to prospective biology teachers' perceptions of the challenges in integrating STEM competencies during micro teaching are shown in Figure 3. The biggest problem for prospective biology teachers in practicing STEM competencies is the increased workload in preparing learning designs (Figure 3). As many as 38% of respondents stated that designing STEM-enriched lessons increased their workload. They need to read many references so that the material to be delivered is multidisciplinary and must master the STEM fields that support the material to be delivered. When teachers experience discomfort in teaching a theme/topic such as STEM-related content that is conceptually challenging, teachers tend to avoid teaching the theme or teach it superficially [16], [20], [26]. The majority of preservice biology teachers feel that they still do not understand STEM integration in learning. However, despite their awareness of the value of STEM competencies, preservice biology teachers still lack perspective on the importance of incorporating the four parts of STEM into every biology class they design. This deficiency affects pre-service biology teachers' decisions about the teaching methods they use in integrating STEM elements [26], [27]. Teachers' lack of understanding of STEM topics, which causes prospective teachers in other subject areas to lack confidence or comfort in their ability to teach STEM subjects, is another factor provided by pre-service biology teachers. There is a correlation between comfort level and efficiency of information delivery in learning. Lack of comfort with STEM subjects among pre-service teachers can negatively impact teachers' impressions of STEM and consequently, negatively impact lesson planning and implementation [22], [28], [29].

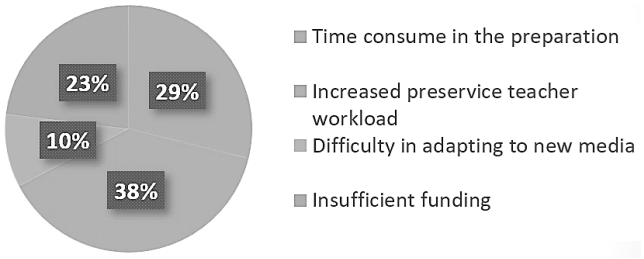

Figure 3. Percentage of pre-service biology teachers' perceptions of challenges in integrating STEM competencies

A total of 29% of prospective biology teachers stated that implementing STEM competencies is challenging. They stated that there are several factors that support their perception; i) it takes a long time to find examples of learning designs that integrate STEM, ii) working together with other friends requires a lot of planning, and iii) reflecting on learning designs that are integrated with STEM competencies also takes time [28]. Biology teacher candidates' perceptions of difficulties in implementing STEM competencies revolve around the need for greater funds compared to regular lesson plans. About 23% of biology teacher candidates stated that integrating STEM competencies into teaching requires a larger budget. They are required to collaborate on aspects of science, technology, engineering, and math in developing lesson plans. They need funds to have direct dialog with science, math and other teachers who have experience in STEM implementation activities in schools. Biology teacher candidates also need to purchase supporting equipment to conduct experiments related to the designed learning activities.

Prospective teachers are strongly encouraged to apply STEM learning in their teaching practice. STEM learning is very effective used where the learning collaborates hands on and critical thinking (method or creativity of prospective teachers in facing a problem that will be resolved with the right solution) [30]–[32]. It is highly recommended for prospective teachers to apply familiarity in solving a problem according to STEM steps. Through STEM competencies, prospective teachers can be trained to think procedurally starting from understanding problems, planning solutions, implementing them planning and checking again. The STEM

approach is a very appropriate approach to use in 21st century learning. After implementing the STEM approach, students are expected to be able to master science and technology literacy through the skills of reading, writing, observing, participating engage in science activities, and be able to develop these skills for use in solving daily life problems. The shortcomings in implementing the STEM learning model are: takes a long time to solve problems, prospective teachers are weak in experiments and gathering information will experience difficulties, there is a possibility that students will be less active in group work, if the topic of each group different, prospective teachers may not be able to understand the topic overall. The implications of this research are very clearly illustrated in the habituation of prospective teachers in designing and implementing STEM-based learning. This research can be used as a reference in providing information about implementing innovative learning in the learning process by applying STEM learning. The results of this research show that implementing STEM learning can help prospective teachers to improve learning effectively and innovatively in the learning process.

4. CONCLUSION

STEM competency topics are important for prospective biology teachers to master because they provide opportunities for prospective teachers to improve performance, think critically, and creatively. So far, many studies have focused on improving the competence of prospective teachers, but there is still no model that is claimed to be able to support STEM competencies appropriately. Through the CRTP model in micro teaching courses, prospective teachers have STEM competencies in designing multidisciplinary teaching. This study concluded that most prospective biology teachers believe that STEM competence is a core competence that must be mastered by prospective teachers. Micro teaching lectures by prioritizing STEM competencies are effectively able to help prospective biology teachers master the collaborative and reflective principles supporting 21st century education. Prospective biology teachers face challenges in integrating STEM competencies, such as time constraints, budget constraints, and increased workload in lesson planning and implementation. They have a positive perception of STEM competencies in micro teaching courses. Collaborative and reflective principles are believed to have a positive impact on the development of biology teacher candidates' skills and competencies during teaching practice. The authors also suggest that prospective biology teachers design lessons by integrating interrelated STEM disciplines, fostering skills related to STEM fields, and implementing STEM competencies on an ongoing basis.

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