Teacher’s Candidate Readiness and Beliefs in teaching STEM: Formulating Best Strategy in Scientific Communication

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Abstract. The application of Science, Technology, Engineering, and Mathematics (STEM) in science learning can facilitate communication interactions between teachers and their students while also encouraging classroom management teachers. However, not all teachers can apply essential principles in using STEM. This research aimed to get information about teachers’ readiness and confidence in preparing, teaching, and evaluating the application of STEM. We also gain some information about the difficulties and difficulties of teachers in using STEM. Data collected through a survey by distributing questionnaires to 50 teachers randomly. Data were descriptively analyzed. The results show that some teachers have not been able to integrate several science fields in an integrated manner and how to evaluate them. This finding is expected to be a recommendation for research into STEM implementation in learning.

1. Introduction

The technological disruption era is snowballing and has had a significant impact on various life fields, including education. All elements of education involved, including teachers and students, must keep up with the times. Teachers and students are expected to mastering technology that is sustainable and integrated with other fields, which changes the way students learn, socialize, and interact daily. Science, Technology, Engineering, and Mathematics (STEM) is a breakthrough approach to education in responding to the demands of 21st-century skills, which requires students to have mastery in critical thinking, creativity, collaboration, communication, information literacy, media literacy, technology literacy, flexibility, leadership, initiative, productivity, and social skill [1], [2]. Interdisciplinary learning is the best way to train students to manage and be actively involved in technological developments [3]. STEM integrates several disciplines at once: Science used to find out and explain the concept of life and also scientific phenomena around us; Technology used to build, enhance and improve nature efficiently; Engineering, used to maintain, modify, or design materials, processes, and systems; and Mathematics then represent facts, phenomena and further understanding of nature through numbers. In STEM, the four disciplines are cohesive and wholly adapted to the real world's problems.

So far, STEM practice has been carried out in various versions, tailored to students' character and the learning environment. There is no standard version of STEM implementation that is declared the most effective because different conditions and infrastructure will produce different results. It found that the participation and performance of students who received STEM learning in rural schools were lower than students in urban areas [4], especially in psychomotor practice. The goal to be achieved in STEM learning is developing student skills to overcome the problems faced through various dynamic and
practical solutions. All of this can be accomplished in several iterative STEM steps that refer to the Engineering Design Process (EGD). The steps in EGD include (1) defining the problem by determining the criteria and limitation of the problem to be looked for a solution, (2) formulating several possible solutions and selecting which one is considered the best to solve the problem, and (3) optimizing the solution it gets through systematic and reliable testing [5].

Some of the competencies that can be achieved in STEM include cognitive, interpersonal, and intrapersonal skills. Cognitive competencies include critical and creative thinking skills; interpersonal competencies include communication skills, collaboration, responsibility, and intrapersonal competencies, including flexibility, initiative, and metacognition [5]. On this occasion, this research will pay special attention to interpersonal skills, especially scientific communication, carried out in STEM learning. Effective scientific communication cannot be separated from the cognitive skills used to interpret and convey messages verbally and nonverbally and to provide opinions and responses appropriately [6].

Scientific communication is one of the skills that support students to develop advanced science skills and general strategies to optimize independent learning and do so in order to achieve scientific literacy[7]–[9]. In learning, open communication between students and teachers allows them to collect the same knowledge and information, neither party acts as a determinant of truth. When a person makes a statement based on evidence and is presented publicly, the other party can evaluate, oppose, adjust, or deepen that person's ideas or methods for further investigation. The scientific truth of a thing emerges with this process [10]. This phenomenon shows that scientific communication is crucial to be applied in all things so that the essence of science is maintained, namely the exchange of ideas, ideas, and evidence freely but still structured.

However, practically, not all students can be actively involved in scientific communication during the learning process. The results of observations and interviews with several teacher candidates who became apprentice teachers in several junior high schools showed that in one class, on average, more than 50% of students were passive; some answered if the teacher asked questions or asked for responses. However, only a small proportion took the initiative to ask questions, responding, or answering without being asked. Class discussion and question-answer activities were only dominated by a handful of students, even though the teacher had tried to give equal attention to all their students. Besides, time constraints and demands for completing dense material on time make teachers less likely to optimize discussion and question and answer sessions.

Random interviews with several science teachers show that some teachers admit to having limited knowledge about STEM, especially in terms of integrating multidisciplinary concepts so that they often feel less confident in implementing STEM. Other teachers argued that even though they had mastered content knowledge, in its implementation, they found it challenging to implement effective STEM learning strategies through appropriate representations so that they often failed to link interdisciplinary concepts in an integrated and proportional manner.

There have been many studies on applying STEM at various levels of education, from elementary school to university, for several purposes, such as improving higher order thinking skills, participation, motivation, and creativity. The shift in STEM practice towards active and student-centered learning implicates that this learning approach cannot be made spontaneously but through proper planning. As the executor, the teacher must have basic and advanced knowledge about the ins and outs of STEM, plan, implement, evaluate, and use the media. This preparation is critical to ensure that STEM learning has been carried out according to procedures and meets the expected learning objectives. For this reason, this study needs to be carried out to prepare teacher candidates in implementing active and participatory STEM, especially in terms of improving classroom discourse in the form of scientific communication. Through scientific communication skills in STEM learning, students become better and open in communicating what they have achieved, asking for help from teachers or friends if needed, and expressing what they apply. Besides, over time they will develop skills and confidence in sharing more clearly what they have done in class and integrating science concepts in an integrated manner in STEM.
1.1. Statement of the problems
Most teachers’ candidates experience confusion about carrying out learning with an active and participatory STEM approach in the science class, especially in the lesson plan, including the media used, evaluation, and the instruments used. So far, teachers’ candidates have not received uniformity of knowledge on how to package communicative, interactive STEM learning, which has led to active student participation in the classroom discourse, especially in scientific communication.

1.2. Research objectives
The research aims to gain information about:
1. The readiness and beliefs of teachers’ candidates in preparing, teaching, and evaluating the implementation of STEM to improve scientific communication.
2. The barriers and difficulties of teachers’ candidates in preparing STEM practice to improve scientific communication.

1.3. The scope of the study
This research is limited to the following matters:
1. The teacher candidates in question are students in the Science Education Program who are currently doing internships at schools.
2. Activities to explore teacher candidates' readiness and confidence in planning lessons using the STEM approach include evaluation of lesson plans, materials, and media planning.
3. Scientific communication consists of verbal and non-verbal activities that create interaction between teacher-students and between students in discussing science problems around them.

We hope this research provides the necessary information regarding the problems of teacher candidates in planning STEM learning in real classrooms so that they can anticipate confusion and provide the expected standard knowledge regarding STEM practice in science classrooms.

2. Methods
This research is a quantitative descriptive study that aims to carefully and systematically describe the facts and characteristics of specific populations, in this case, the readiness and confidence of prospective teachers in teaching through a participatory STEM approach and the obstacles they experience.

2.1. Participants
The participating teacher candidates come from students enrolled in the science teacher education program in semester sixth and have taken learning innovation courses. The number of participants was 40 people ranging in age from 20-22 years.

2.2. Procedures
Participants are invited to complete the task of making lesson notes and learning instruments during regular online class sessions. Previously, they had been allowed to deepen STEM learning materials independently. On average, it took participants five days to complete the task and survey.

2.3. Data Analysis
Data from participant responses were analyzed descriptively to develop an overview of teacher candidates' characteristics in preparing for STEM learning. Readiness is assessed from the lesson notes they have worked on, including the components of Introduction, Learning Outcome, Structure, Activity, and Learning Source. Furthermore, the teacher candidate's readiness was categorized based on four criteria, namely Ready, Approaching Readiness, and Developing Readiness. Meanwhile, tracing the obstacles experienced in preparing for STEM learning was taken from the survey results.

3. Findings and Discussion
Based on the observations made, the following results were obtained:
3.1. The readiness of teacher candidates in making active and participatory STEM lesson notes

The table below shows that most of the teacher candidates are categorized as "ready" in making lesson note components containing students' scientific communication activities in the "opening" and "learning outcome" sections. In the "opening" component, most teacher candidates can present practical STEM-related problems that students often face so that students are expected to be more enthusiastic and focus on the material given. Even so, there are still 10% of teacher candidates who have not written opening materials that attract students' interest. The rest can present material related to the real world, but not through presentations that attract students to explore further.

In the learning outcome component, most teacher candidates were also included in the "ready" category. They can describe learning outcomes based on the syllabus, basic competencies, determine appropriate performance achievement indicators, and show student activity cognitively and psychomotor. The rest are still not careful in writing performance achievement indicators not to show student activity.

The components of "structure," "activities," and "learning resources" are components of lesson notes that are found to be the most difficult for teacher candidates to be done. Most of them only got the "Approaching Readiness" category. In the "Structure" component, it is seen that most teacher candidates have not included activities that connect teachers and students according to the iterative Engineering Design Process (EGD) steps, namely (1) defining the problem, (2) formulating problem-solving, and (3)) Optimizing solutions and reliable testing. The EGD steps that were made were still very general and did not match the expected learning objectives.

Furthermore, in the "Activity" component, student activities in making observations, formulating problems, and hypotheses presented generally, are not specific. Besides, there are still many activities to communicate data, statements, and ideas that are not clearly stated. Teacher candidates' difficulty in keeping active and participatory STEM lesson notes is likely also due to the lack of learning resources used. This incident is still found in the "Learning Source" component, where many teacher candidates have un-up-to-date textbooks. Some use student activity-based learning resources to present the latest science that attracts students to discuss, but most of them are still old books or just worksheet written by the previous teacher.

| Lesson Notes Component | Readiness Category (%) |
|------------------------|------------------------|
|                        | Ready                  | Approaching Readiness | Developing Readiness |
| Opening Activity       | 60,0%                  | 30,0%                 | 10,0%               |
| Learning Outcome       | 52,5%                  | 42,5%                 | 5,0%                |
| Structure              | 45,0%                  | 50,0%                 | 5,0%                |
| Activity               | 37,5%                  | 52,5%                 | 10,0%               |
| Learning Source        | 37,5%                  | 45,0%                 | 17,5%               |

3.2. Teacher’s candidates beliefs in teaching active and participatory STEM
Figure 1. Teachers’s candidates beliefs in teaching STEM

Based on the survey conducted, it was found that the teacher candidate's belief was still low in terms of managing class management, giving student instructions, especially in actively communicating scientifically, applying integrated science concepts, and providing assessment based on student communication activities. This is shown in Figure 1. above. Class management includes optimizing classroom settings appropriately through significant learning time and counterproductive instruction time. It is essential to allow students to learn and do discipline and time efficiently [11], especially when conducting presentation discussions. Regarding student motivation, the teacher must be able to encourage students to learn strongly. Student achievement depends on student motivation as well as their cognitive abilities. Intelligent students who are not motivated can learn less than highly motivated students even though they have lower cognitive abilities [11]; moreover, motivation is influenced by emotion [12].

3.3. Designing Scientific Communication in STEM

Figure 2. Design of Scientific Communication Activity in STEM

Getting students used to active scientific communication in learning is not an easy thing. Apart from requiring adaptation and habituation, this activity must be planned properly and carefully, starting from the necessary tools, initial planning, lesson plans, and implementation in class (online and offline, if necessary), including making reflections and evaluations in learning (see Fig. 2 above). The following
is an illustration of how to design STEM learning that raises student scientific communication activities in the classroom.

| No | Stages            | Activity                                                                 | Instruments                                                                 |
|----|-------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------|
| 1  | Preparation       | The teacher determines STEM learning resources based on hands-on activities that contain scientific phenomena experienced by students so that argumentative and interesting discussion material can be created. | Obtained:                                                                  |
|    |                   |                                                                          | 1. A representative learning resource                                      |
|    |                   |                                                                          | 2. Schematic design of real student activity activities                  |
| 2  | Lesson Plan       | The teacher makes a complete STEM lesson plan, starting from the Opening Activity stage, Learning Outcome, Structure, Activity and Learning Source, referring to the syllabus and learning objectives accompanied by timing at each stage. | Obtained:                                                                  |
|    |                   |                                                                          | 1. A representative lesson plan                                           |
|    |                   |                                                                          | 2. The design of student activities accompanied by timing                 |
|    |                   |                                                                          | 3. Representative and communicative classroom arrangement design         |
| 3  | Implementation    | The teacher implements STEM learning following the Engineering Design Process (EGD) steps, which contain students' scientific communication activities, especially when discussing ideas and communicating the students' work or projects. | Obtained:                                                                  |
|    |                   |                                                                          | 1. A representative student performance appraisal sheet                   |
|    |                   |                                                                          | 2. Student activeness observation sheet                                    |
|    |                   |                                                                          | 3. Student scientific communication observation sheets, including the number of questions, responses, and answers of students |
| 4  | Reflection        | The teacher reflects with the students about the STEM learning that has been carried out. Focus is given to students who have not actively participated and communicated scientifically in learning. The teacher provides input and suggestions for further learning. | Obtained:                                                                  |
|    |                   |                                                                          | 1. Teacher notes                                                         |
|    |                   |                                                                          | 2. Reflection sheets from students                                         |
|    |                   |                                                                          | 3. Sheet of suggestions and complaints from students                      |
| 5  | Evaluation        | The teacher evaluates the implementation of STEM, highlighting the students' scientific communication skills | Obtained:                                                                  |
|    |                   |                                                                          | 1. An assessment sheet for the quality of students' scientific communication skills orally or in |
writing (referring to the quality of data, reasoning, and evidence).
2. Documentation and portfolio (if necessary) of student communication activities

4. Conclusion
Teachers' difficulties and obstacles in teaching need to be identified in order to find the best solutions to overcome them. The results of research regarding the readiness of teacher candidates in planning STEM learning that are able to accommodate students' communication skills indicate that:
1. There are still many teacher candidates who are not ready to design STEM learning that accommodates students' scientific communication skills, especially in the "Structure", "Activity", and "Learning Source" components.
2. Most teacher candidates have difficulty designing class management, giving student instructions, especially in actively communicating scientifically, applying integrated science concepts, and providing assessment based on student communication activities.

The results of this research need to be followed up through intensification of knowledge and practice of STEM learning for teacher candidates, especially before they actually teach in real classrooms. Constraints, difficulties and problems regarding STEM learning preparation that can stimulate students' scientific skills will then become the data and basis for further research that will be carried out later.

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