STEM education for pre-service teacher: why and how?

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Abstract. The success of STEM implementation in primary and secondary schools is greatly influenced by the role and expertise of the teacher. In the Indonesian context, not many universities have STEM centers yet. This paper wants to describe the STEM education design for pre-service science teachers at Universities. The method used was a Focus Group Discussion from several researchers with backgrounds in physics, chemistry, and biology across universities. The results of the study show the importance of developing STEM education programs in certain subjects, applying STEM learning to pedagogical practices, open courses that specifically train, develop STEM teaching for pre-service teachers and build the STEM center. This study concludes the importance of an integrated program between preparing STEM education at universities and implementing STEM in the field.

1. Introduction

STEM education has been adopted by many countries as a blueprint for educational innovation so that it emerged as a global movement to bridge the gap between the needs and the availability of expertise needed for economic development in the 21st Century [1]. Many stakeholders hope that by implementing STEM learning, the quality of education in a country will change for the better. Various types of approaches have been done. Various experts and scientists from different fields contribute to developing. However, it cannot be denied that the success of STEM learning implementation in schools depends on the expertise of the teacher in bringing learning. The successful implementation of STEM at the elementary and secondary school level is influenced by how well-preparing teacher candidates are at the University [2].

In the context of education in Indonesia, the area of research and implementation of STEM is still dominated by primary and secondary school levels [3,4,5]. At the university level, STEM implementation is only used as an approach to one topic in a particular subject. Not many universities have opened STEM centers and opened specialized courses on STEM. Some experience in the field
shows that there are phenomena where prospective teachers have to implement STEM in schools while practicing their pedagogy while they have not gained experience in implementing STEM. After having discussions with research teams across universities, the same lessons were experienced and felt.

Therefore, the more massive discourse on STEM education implementation at the University level needs attention.

Previous studies on the implementation of STEM education show the importance of the implementation of STEM learning integrated with multidisciplinary, interdisciplinary and transdisciplinary approaches [6]. The researchers suggest that STEM learning in universities must integrate learning theory, pedagogical approaches, and build awareness about the results of current STEM education initiative research [7]. There must be a shift in learning approaches from the type of separated to integrated learning that accommodates sociocultural and socioscientific theory and practice [8]. Even as the complexity of the problems faced by students and the fact that STEM education is a complex social phenomenon, space for collaboration with other scientific disciplines including sociology is very possible. There is an important role played by social-psychological attributes in student success in STEM education. This is an area where sociologists can take a role [9]. This study wants to reveal the urgency of STEM education for prospective teachers and how the series of efforts to carry out STEM education at the University.

2. Method

This study uses the Focus Group Discussion (FGD) method. FGD has developed into a valuable way for collecting qualitative data [10,11]. FGD is very good for exploring perceptions, feelings, and thoughts about problems, ideas, products, services, or opportunities [12]. The stages of the FGD in this study include; (1) Determination of research design, including determining research objectives, determining participants, and location (2) Data collection, both before and during the meeting (3) Data analysis, and (4) Results and reporting [13]. FGD was held twice, in the middle of the even semester of the 2018-2019 academic year. The first FGD was at UIN Sunan Gunung Djati Bandung and the second was held at Majalengka University.

The discussion focused on two main issues, namely answering the importance of STEM education at the undergraduate level and how to organize STEM education at the undergraduate level. Based on its type, FGD in this study was categorized in the expert group by presenting several experts in science and science education, including physics, chemistry and biology across universities [14]. The FGD was conducted in two modes, namely off line and on line discussions. Off line discussions were carried out by researchers from nearby universities (UIN Sunan Gunung Djati, Bandung and Majalengka University). While the online discussion was conducted by researchers with a long distance university (UIN Sultan Thaha Saifuddin, Jambi and UIN Ar-Raniry, Banda Aceh).

Data collection was carried out through questions and answers and discussions about the problems of implementing STEM at the university. Each participant was given the opportunity to express their opinions and share their experiences. All answers, comments, and ideas during the discussion were recorded by the note-taker and recorded through a recording device. All discussion data were analyzed through the process of listing, coding, content analysis, discourse analysis, and conversation analysis. The results of this study were made into a report to be followed up through an advanced program.

3. Result and Discussion

3.1 The Importance of STEM Education in Universities

Discussions about the importance of STEM education at the University are driven by an urgent need to take concrete steps in preparing prospective teachers who are ready to implement STEM in the field. Researchers with different scientific backgrounds and from various universities are trying to formulate efforts to animate STEM education at the University. If the institutions of higher education do not begin to address concerns about the quality of undergraduate STEM, it does not preclude solutions with
potentially questionable outcomes that can be externally imposed, the same as those applied to primary and secondary education [15].

As a first step, the research team who felt the same problem gathered to discuss concrete steps to realize STEM learning for prospective teachers. The first discussion began with a SWOT analysis of the existing conditions of each university. This step was taken to map out the problems and their potential. SWOT Analysis is part of strategic planning that helps organizations become more productive by helping to guide the allocation of resources to achieve goals [16]. The SWOT analysis can be a tool to bridge the gap between methodological challenges and the implementation of impact measurement in systematic quality management [17]. Table 1 below shows the results of a SWOT analysis from the research team. By conducting a SWOT analysis, the research team can design the program following the conditions of the problem encountered and its potential.

### Table 1. SWOT Analysis

| Strengths | Weaknesses | Opportunities | Threats |
|-----------|------------|---------------|---------|
| ▪ Many expert lecturers, both in education and in mathematics, science (physics, chemistry, and biology), as well as engineering | ▪ There is no Ph.D. in STEM | ▪ Research on STEM will continue to be interesting to study | ▪ Changing curriculum policies |
| ▪ It is possible to work together across faculties | ▪ There is no STEM Center in the Faculties and Universities | ▪ It takes many STEM experts both at the university and at the School | ▪ Difficult to improve the learning paradigm |
| ▪ Can collaborate with cross-disciplines such as religion and humanities | ▪ Lack of facilities | ▪ STEM education can be a 21st-century learning approach | ▪ Educational institutions that are less supportive |
| ▪ Lack of funding | | | |

With its strengths, especially in the aspect of human resources, organizing STEM education at the university level will be more accessible. In the early stages, scientists and engineers who, with in-depth disciplinary knowledge, can offer leadership, especially designing ways of incorporating attention into emerging fields and practices in science and engineering [18]. It is undeniable; the success of developing programs also depends on the structural aspects of leadership. Therefore, experts in the STEM field must collaborate with policyholders. The institutional part that is very difficult to understand is that many interconnected components act simultaneously on the people involved and the instructional choices made [19].

In addition to expert collaboration and policyholders, an equally important part of the effort to revive STEM at the undergraduate level is a cultural change. Cultural change is needed for meaningful STEM institutional reform. Creating cultural change on campus will require a complex and multi-faceted approach and a strong understanding of institutional culture, as well as attention to sensing strategies, organizational learning, multi-frame thinking, and multi-level leadership [20].

### 3.2 How to organize STEM education at the University level?

Based on the SWOT analysis, the research team formulated several alternative STEM arrangements at the University based on the order and visibility of the implementation. Table 2 below shows some methods that can be chosen with descriptions and examples.
Table 2. How to Organize STEM Education in Universities

| Method                                      | Description                                                                 | Example                                                                 |
|---------------------------------------------|-----------------------------------------------------------------------------|-------------------------------------------------------------------------|
| Insert a STEM approach in existing courses  | STEM as a learning approach can be used in existing courses, both content and pedagogy courses | STEM in physics course, STEM in Mathematic course[21,22]                 |
| Applying STEM learning to pedagogical practices | STEM can be used as a learning approach when students take micro-teaching and professional practice in school | Students are trained to use STEM as an approach when they learn to be a teacher, both during microteaching and infield practice. In microteaching, they can practice with lecturers. At school, they can work together with professional teachers |
| Open courses that specifically train and develop STEM | STEM education will be more effective if it is explicitly presented in a course | In each department, such as physics education, biology education, chemistry education open special course about STEM, either as compulsory subjects or elective courses |
| Joint projects across department           | STEM can be used as a joint project across departments; carried out routinely and continuously | The Department of Physics, Biology, and Chemistry creates joint STEM practice programs every semester; The program was designed by each lecturer representative involving students |
| Established STEM center                    | The STEM Center is built at the Faculty or University level if four previous programs have been implemented. | After all, components are ready (experts, facilities, programs, funding), the faculty of education, or the University can create a STEM center. The STEM Center will become a permanent institution that develops learning, research, and service programs in the STEM field |

Three essential things must be done related to the implementation of STEM at the university level, as revealed by The Association of American Universities (AAU): pedagogy, scaffolding, and larger cultural change [23]. Related to pedagogy, lecturers are not only required to transfer knowledge to their students. Providing best practices from those already experienced and implemented will be far more effective. One of the most significant barriers to improving undergraduate STEM education is the lack of knowledge on how to effectively disseminate the use of ideas and learning strategies that are currently available based on proven research results [24]. Four strategies are proposed to achieve undergraduate STEM goals: (1) implementing evidence-based instructional practices and innovation to enhance undergraduate STEM learning; (2) focus on STEM education in two-year colleges and build bridges for a four-year program; (3) Expanding partnerships outside of higher education to provide initial research experience; and (4) Address the gatekeeper issue of beginning college mathematics [25].

Still related to pedagogy, there are two crucial things in preparing STEM teachers: (1) STEM pre-service teachers need to understand the concept of integration and how to teach STEM, not as a silo approach. (2) The objectives of STEM education must be clear to pre-service teachers based on educational purposes. The STEM teacher preparation program must be different from the science teacher preparation, technology teacher preparation, or mathematics teacher preparation program because it represents the integration of scientific disciplines [26]. Teachers produced through the correct education process will become STEM teachers who can continuously develop production pedagogy by redrawing and contextualizing science and technology education in a significant way [27].

Starting a STEM undergraduate education requires enthusiasm and hard work. A clear road map is needed, as outlined in a planned and measured program. Setting up scaffolding is a significant effort. Keck / PKAL is an example of a model. This model provides process and content scaffolding for campus leaders to plan, implement, assess and evaluate change efforts in undergraduate STEM education in a way that goes beyond redesigning a single course or isolated program [28]. For this program to go
according to plan, explicit administrative approval, encouragement, recognition, and financial support from the faculty are needed [29].

The last factor that is very important in maintaining and growing undergraduate STEM education is a cultural change. There must be a fundamental change, albeit slowly, to ensure that all relevant parties commit to change the lecture curriculum for the better. Previous research shows that cultural change requires increasing attention by project leaders to how all STEM departments involved with the project show signs of wanting to change [30].

4. Conclusion

This study concludes the importance of STEM education at the undergraduate level. Ways to teach STEM to pre-service teachers can be made in five ways: (1) Implement STEM learning in one lecture topic, (2) Apply STEM learning to pedagogic practices (3) Open specialized courses on STEM (4) Conduct STEM projects across departments and (5) Establishing STEM centers. After these five components are formed and running, the next step is to ensure that STEM undergraduate education can produce professional teacher candidates who have a positive attitude and can bring STEM learning in school.

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