Analysis of the needs of science, technology, engineering and mathematics (STEM) learning instruments on the derivative topic

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Abstract. STEM (Science, Technology, Engineering, and Mathematics) is an approach which combines or fuses science, technology, engineering, and mathematics into education program to improve students’ learning potential. STEM is started to be disseminated by the government to provide a push for the realization of Industrial Revolution 4.0 in this century. The purpose of this study is to describe the necessity of STEM learning instruments on the derivative topic. This study is part of the developmental research on the preliminary stage, which is the needs analysis. Three of eleventh-grade math teachers were invited to participate in this study. The questionnaire about various aspects of the needs analysis was given to the teachers. The study results found that the teachers agree to develop STEM learning instruments on the derivative topic and are interested in examining the instruments if they are accessible for them.

1. Introduction
The 21st-century development does not solely depend on reading, writing, and calculation abilities, but also must be combined with creativity, communication, collaboration and critical thinking so that learners would be gifted to confront complex, realistic problems [1]. Therefore, curriculum instruments and 21st-century teaching methods are enormously important in the preparation process for students to face their future [2].

Mathematics is not a separated standard, but rather an integrated subject. Thus, in mathematics, we need to learn and think about connections in scientific disciplines, as reflected in particular class curricula and between grade levels [3]. There is an approach that integrates some disciplines or known as STEM (Science, Technology, Engineering and Mathematics). STEM is an approach that explores teaching and learning methods between two or more related subjects, and or between kindred subjects and other school subjects [4].

STEM approach has been applied in the United States and becomes the spotlight of local government. There are even specialized institutions to compose reports which explain criteria to indicate effective STEM program to be followed later [5]. Through the Ministry of Education and Culture, the Indonesian government are welcoming the Industrial Revolution 4.0 with STEM practices. Efforts to disseminate and initiate the STEM approach in a learning process have been carried out by various parties; this is portrayed in the practice approach of the learning process in schools. It is expected that through the STEM approach, the students learn not only math but also the
importance of mathematics. Therefore, teachers must perceive the needs of their students, the matter that had been learned from the previous years, and what to be learned in the upcoming class [6].

Teachers are education designers whose job is to design the learning concept with a valid purpose. Teachers utilize specific knowledge and skills to identify and frame learning challenges and overcome them using appropriate learning models, strategies and technologies. Being an educational designer needs a modern mindset, an extensive range of skills, and high-quality devices [1].

In Indonesian curriculum, the derivative is first studied at eleventh grade in senior high school (Regulation of the Indonesian Ministry of Education and Culture Number 24 of 2016/Permendikbud No. 24, 2016), which is also one of the fundamental concepts covered in calculus. The derivative has been tightly linked to the concept of memorization with mathematical symbols and the use of suitable formula up to now [7]. Also, the derivative contributes a lot to many other fields, such as physics [8] and computer technology [9]. This is in line with the Regulation of the Indonesian Ministry of Education and Culture Number 24 of 2016 (Permendikbud No. 22, 2016) which requires learning concepts to pay attention to learning principles; one of which is the use of information and communication technology to increase efficiency and effectiveness of the learning process [10] and learners need to be able to apply the concept of the derivative in everyday life [11].

There are also a number of Indonesian researchers who conducted research related to the STEM approach in an effort to apply the STEM approach in the learning process. Based on the results of the study [12], it was found that mathematics teaching materials developed using the STEM approach are remarkably interesting for students and teachers. Dadang [13] mentions that students’ problem-solving ability enhanced with the integration of the STEM approach is better than that of those who get conventional learning method. However, the development of learning instruments integrated into other fields of science is still limited. Therefore, it is necessary to develop learning instruments for STEM on the derivative topic. One of the stages for learning instrument development is to analyze the needs of the STEM learning instruments on the derivative topic [14]. As such, the formulation of the research question is “How is the characteristic of the science, technology, engineering, and mathematics (STEM) learning instruments needed for the derivative topic?

2. Method
The purpose of this study is to describe the needs of STEM learning instruments on the derivative topic. This research is a part of developmental research in preliminary research, that is, the needs analysis [14]. The participants in this study were three math teachers who taught the derivative in the eleventh grade of Senior High School 3 Banda Aceh. Each of them was given a questionnaire that contains a number of questions about the needs analysis as showed at Table 1. Data from the questionnaire were analyzed descriptively to get a picture of the needs of STEM learning instruments on the derivative topic. The interview was conducted to clarify their reason. The questionnaire had been validated by two experts.

| Analyzed aspect                        | Number of question (item) |
|----------------------------------------|---------------------------|
| Concept analysis                       | 5                         |
| School technology facility analysis    | 5                         |
| Knowledge of STEM analysis             | 6                         |
| Existing learning instrument analysis  | 7                         |
| User/needs analysis                    | 4                         |

*Adapted from [14]
3. Result and discussion

Based on the data obtained from the questionnaire, the results for each aspect will be described in the following.

3.1. Concept analysis

| Question                                                      | Teacher 1       | Teacher 2       | Teacher 3                                                                 |
|---------------------------------------------------------------|-----------------|-----------------|--------------------------------------------------------------------------|
| What difficulties did students have so far in learning the derivative? | Fraction        | Fraction        | Applying the derivative concepts in higher-order thinking skills (HOTS) problems |
| What is the prerequisite(s) needed by students before learning the derivative? | Limit           | The prerequisite needed before learning the derivative is the limit of functions | Limit. Basic algebra                                                     |
| What is your method(s) to explain the derivative concept to students? | Using graphs/illustrations | Explaining and presenting PowerPoint slides related to the limit of functions | Using the definition of $f'(x) = \lim_{x \to 0} \frac{f(x+h)-f(x)}{h}$: and the characteristics of the derivative |
| Do you use any media/tools in teaching the derivative?        | Yes             | Yes             | Rarely                                                                  |
| What media/tools do you frequently use?                       | PowerPoint      | PowerPoint      | Laptop                                                                  |

Based on Table 2, it can be seen that all three teachers mentioned limit as a prerequisite that must be learned by the students before learning the derivative and two of them introduced the derivative to students through the definition of limit. This case is in accordance with the content of the eleventh-grade math textbooks that the limit concept is set as the prerequisite for the derivative [11]. However, none of the teachers mentioned the limit as a difficult topic. Two teachers mentioned that fraction as a complicated topic, and another stated the derivative application in HOTS problems.

The teachers were familiar with the use of technology in the learning process. Two of them admitted that they tended to use PowerPoint to deliver the lesson. Learning media were not only PowerPoint and laptop as mentioned by the teachers, but also other tools that can significantly reduce the learning difficulties [15]. A study found that there is an increase in students’ understanding of calculus using GeoGebra software [16]. The use of the software to learn the differential calculus is an excellent tool that enables students to have independent and interactive learning [17].

The interview results discovered that two teachers used PowerPoint only to display some materials. While the other one did not use any technological media to teach the derivative but instead used direct teaching. The following are vignettes of interviews with one of the teachers.

Q: Do you mean just verbal text? Is there any motion in it?
T2: For the last meeting on the derivative topic, there isn’t.
Q: Oh, there is no motion?
T2: There isn’t, just PowerPoint that contains teaching materials
Q: Do you use graphics in teaching the derivative?
T2: Coincidentally when I teach the equation of a tangent line, I use GeoGebra
Moreover, the researchers conducted further interviews with the teachers who answered "laptop" as media they often used. The following are the interview vignettes.

Q : What do you mean by a laptop?
T3 : Media laptop, there are some applications on the laptop.
Q : What application do you frequently use?
T3 : I rarely use applications, honestly. On the derivative topic, I prefer explaining.
Q : A direct learning, isn’t it?
T3 : Yes, it is.
Q : Which means, you don’t use any media? Like PowerPoint?
T3 : Yes, I directly explain all of the lessons, how to find derivatives, basic derivative rules, and so on.
Q : Why don’t you use any media?
T3 : Because, honestly, I think teaching the derivative assisted by media like PowerPoint makes students not to concentrate on the lesson, they’ll focus more on the images. But, for instance, they learn while listening and reading, they’ll observe and follow while I’m explaining. Therefore, it will make them more focused. If I use PowerPoint and move the slides, the students will have no time to look back. But, if I use the board, they can observe it again and continue to write.

Q : Do you use any assistance like GeoGebra software, for example?
T3 : I use GeoGebra just for graphic images.
Q : Do you mean GeoGebra is used to teach the derivative?
G3 : Hmmmm no. Usually, I utilize it for tenth-grade topics, such as inequalities, irrational, absolute values, and graphs of functions.

Based on the interview results, it was found that the teachers did not use any technology media in the learning process, especially for the derivative topic. This issue is contrary to the principles of learning set to improve the efficiency and effectiveness of learning [10].

3.2. School technology facility analysis

| Question | Teacher 1 | Teacher 2 | Teacher 3 |
|----------|-----------|-----------|-----------|
| Are there any technology facilities in your school? | Yes, there are | Yes, there are technology facility | Yes, there are |
| Are there math laboratories in your school? | None | There are no math laboratories | None |
| Have you ever used a technology facility? | Sometimes | Yes | Rarely |
| Have students ever used technology facility? | Rarely | Yes | Yes |
| Are the facilities enough to meet the student's needs? | Not yet | Not enough yet | Lacking |

Table 3 shows that there were technology facilities in the school; however, they were not sufficient to meet the needs of the students. Nevertheless, the teachers’ assumption about the lack of facilities that barely supported the needs of the students made them reluctant to use the existing technology facilities. It is pictured from the teachers’ answers to the question related to the use of the existing technology facilities. ‘Sometimes’, ‘ever’, and ‘rarely’ represent the teachers’ answers to such a question. This is in line with the response to the question in relation to the use of the existing technology facilities. Two of them answered ‘sometimes’; whereas, one of the principles that must be
given attention in designing a lesson plan is integrated, systematic, and effective information technology appliances corresponding with the concrete situation and condition [10]. This argument is in line with a study mentioning that the use of technology is crucial in the teaching and learning process, especially in math [3]. Also, technological devices must be adopted and used with the method that corresponds with teaching purposes.

Lack of current facilities is not necessarily become a primary factor which causes the limited use of technology facilities in the learning process at the school, especially for the derivative topic.

3.3. Knowledge of STEM analysis

Table 4. Teachers’ responses to the aspect of knowledge of STEM analysis.

| Question                                                                 | Teacher 1          | Teacher 2          | Teacher 3          |
|-------------------------------------------------------------------------|--------------------|--------------------|--------------------|
| Have you ever heard the word STEM (Science, Technology, Engineering, and Mathematics)? | Yes                | Yes                | No                 |
| When did you hear STEM for the first time? (just assumption)            | Three months ago   | Two months ago     | Today              |
| From whom did you get the information about STEM?                        | From the seminar   | From the seminar   | From this questionnaire |
| Are you interested in STEM?                                              | Yes                | Yes                | Yes                |
| Has STEM ever become a discussion topic with fellow teachers?            | No                 | No                 | No                 |
| What is your response related to STEM?                                  | Good, interesting | Interesting to learn | Looks interesting |

Table 4 presents that two out of three teachers were interested in the STEM approach. Both of them had participated in a STEM seminar. However, it seems like the other teacher was still less enthusiastic, by responding “looks interesting”. This might be caused by the lack of information about STEM obtained, and the fact is the teacher just heard about STEM from the questionnaire. The finding of this study revealed that there were teachers that had not known about STEM yet, even one of the teachers heard the term for the first time while reading the questionnaire. The other two had heard about it when participated in a seminar about 2-3 months ago. Internal and external factors may contribute to this issue.
3.4. Existing learning instrument analysis

Table 5. Teachers’ responses to the aspect of existing learning instrument analysis

| Question                                                                 | Teacher 1 | Teacher 2 | Teacher 3          |
|-------------------------------------------------------------------------|-----------|-----------|--------------------|
| Are you satisfied with the learning instruments you have so far?         | Yes       | Yes       | Not Satisfied Yet  |
| Do the current learning instruments have any weaknesses?                 | Yes       | Yes       | Yes                |
| What change/improvement could be done to overcome the weaknesses?        | -         | Searching interesting and innovative learning instruments | Using learning media and learning model |
| Are the designed learning instruments integrated with media/technology?  | Rarely    | Rarely    | Yes                |
| Have you ever seen/learned a STEM lesson plan?                          | No        | Not yet   | No                 |
| Have you ever seen/learned a STEM lesson plan on the derivative topic?  | No        | No        | No                 |

STEM seems a new term for all of the three teachers, and eventually, they had not seen a STEM lesson plan yet as shown at Table 5. However, they were willing to learn and implement it in their classroom.

The interview results discovered that Teacher 3 felt unsatisfied with the existing learning instruments due to their inaccessibility for the derivative topic, as presented in the vignettes below.

P : Why do you feel unsatisfied with the existing learning instruments?
T3 : Because the learning instruments that I have are not accessible for students. How can I say I am satisfied?

P : What are the shortcoming of using the learning instruments?
T3 : The shortcoming is time. The students are busy with activities and solving problems. I think Curriculum 2013 still has some weaknesses. The application of the materials is not sufficient.

P : Do you mean the application?
T3 : See, the learning instruments are available but not with the application. The Curriculum 2013 is fickle, isn't it? It keeps changing.

P : How about the contents in the learning instruments? Are you satisfied with the instruments?
T3 : There is a weakness in the learning instruments. The integration of technology in learning is still limited.

P : You don’t use any technological media, do you?
T3 : Yes, indeed, that's the shortcomings that make me unsatisfied with the learning instruments.
3.5. User/needs analysis

Table 6. Teachers’ responses to the aspect of user/needs analysis

| Question                                                                 | Teacher 1       | Teacher 2                                      | Teacher 3                        |
|--------------------------------------------------------------------------|-----------------|------------------------------------------------|----------------------------------|
| Have you ever received a STEM learning instrument for the derivative topic? | No              | No                                            | No                               |
| If you are handed a STEM learning instrument on the derivative topic by college students, teachers, or lecturers, will you try to learn it? | Yes, God willing, I will try to understand it | Yes                                            |
| If you have understood how to use a STEM learning instrument on the derivative topic, will you apply it in your classroom? | We will apply it | Yes                                            |
| What do you expect from a STEM learning instrument on the derivative topic? | Hopefully, the learning process using a STEM learning instrument, students will be more active and creative | Conceptual understanding of the derivative through technology and its application |

Table 6 shows that the teachers never received a STEM learning instrument for the derivative topic. All the three teachers will try to learn it if they have it and will apply the instrument if they have comprehended it. They expect that STEM learning instruments would make students more active, creative and innovative, and could improve students’ conceptual understanding of the derivative through technology and the application.

Expectations expressed by the teachers have reasons. It is in line with Kilbane [1], who stated that what happens to students inside the school is highly influenced by what happens to them outside the school. There are five primary trends; one of which is technology, as fuels and tools toward the change of education.

4. Conclusion
This study found that fraction dominantly becomes a problematic concept in learning the derivative. In the school where the teachers are teaching, there are some technology facilities, but they are not sufficient enough to fulfil the students’ needs. The use of technology in mathematics learning is still lack of intensity. The teachers are interested in the STEM approach, but it has not yet become a discussion topic among teachers in the school. Also, the teachers never see or learn a lesson plan with the STEM approach, either on the derivative or other topics. However, they support the development of STEM learning instruments on the derivative topic, in line with their interests and desires to learn the learning instruments if provided. The characteristics of the STEM learning instruments needed on the derivative topic are that it enables to encourage students to be more active, creative and innovative, and helps to promote conceptual understanding of the derivative through technology and the application.

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