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Improving the Ability of Writing Teaching Materials and Self-Regulation of Pre-Service Physics Teachers through Representational Approach

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Abstract

The research aimed to develop instructional strategies that could improve the ability of writing teaching materials and self-regulation of pre-service physics teachers. The problem under research was how representational approach embedded into physics courses with selected topics could improve the ability of writing teaching materials and self-regulation of pre-service physics teachers. The data were analysed descriptive-qualitatively. Based on data analysis, the following conclusions were drawn: 1) There was a significant difference in the ability of writing teaching materials between students treated with representational approach and those who were treated with expository approach; 2) The ability of writing teaching materials of students treated with representational approach improved with a percentage of average normalized gain that could be categorized into a high-level criterion; 3) The representational approach was effective in improving the ability of writing teaching materials of pre-service physics teachers with a corrected effect size that was categorized as high; and 4) The approach was effective in improving pre-service physics teachers' self-regulation in writing teaching materials with a moderate level of effect size

Keywords: Multimodal representation; writing teaching materials; pre-service teacher; learning to write activity

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1. Introduction

The education program for professionals of education in the field of Mathematics and Sciences aims to prepare professionals of education who have knowledge foundation, technical skills, and professional values and attitudes in planning, conducting, managing instructional activities, developing learning resources, evaluating learning achievements, and solving problems pertaining to the profession in the field in the context of subject teaching [1]. This perspective views teacher not as a storeroom of facts and ideas, but as "a source and creator of knowledge and skills needed for instruction" [2]. Preparing pre-service teachers to be professionals should be focused on the substance, which is what should be learned by the pre-service teachers and the best way to encourage them to learn it. The essential knowledge and skills teachers should have are knowledge about the students and how the students learn and develop in the social context, knowledge and skills on subject materials and curriculum objectives, and the understanding of teaching by considering content and the diversity of the students they will teach [3]. These essential knowledge and understanding of pre-service teachers are also stipulated in the document of Indonesian Minister of National Education Decrees no. 16 of 2007, discussing qualifications of national standard of education and teacher competence in that each teacher is obliged to fulfil the academic and competences standards. The teacher competences standards are developed holistically from the main four components, namely: Pedagogic, personal, social, and professional competences. The four competences are integrated into teacher performance. Pedagogic competence, among others, is mastering the characteristics of students, from their physical, moral, spiritual, social, cultural, to emotional aspects. Social competence includes communicating with a community with the same and different professions, whether orally, in written, or in other forms. Professional competence, among others, is developing instructional materials of the subject that teachers teach creatively, covering: 1) Selecting instructional materials taught according to student developmental level; and 2) Processing lesson materials taught creatively in accordance with student developmental level.

The teacher competence that becomes the focus of this research is the ability to develop instructional materials taught creatively. The developed instructional materials should take students' characteristics into consideration. Teachers should be able to communicate the developed instructional materials both orally and in written in classroom interaction and also with their peers. In other words, teachers should have the ability to write, namely writing teaching materials of the subject s/he teaches and writing scientific research report to their colleagues. The question is how teacher training institutes prepare pre-service teachers to be good teachers as well as good writers of teaching materials.

Teaching material writings are representations of contents, both in the form of teaching notes and modules or textbooks that have to be made in such a way that they are easily understood by students. Content representation in textbooks has a great impact on students: Their cognition, problem-solving skills, and the ability to express their understanding to others [4].

The curriculum of physics education in the institutes of teacher's training in Indonesia has not provided a course specifically aimed to equip student (pre-service) teachers with the skills of writing teaching materials. The knowledge of how to write is currently only taught at courses on language, but the knowledge cannot be applied in writing teaching materials. The existing teaching writing strategies, such as the ones used in teaching language, are not completely adequate to teach writing for pre-service teachers of natural science. Writing teaching materials is different from writing essays or other kinds of writings, because writing teaching materials is related to certain discipline that becomes the theme or main idea of it. The content of the discipline in teaching material writing has to be free of misconceptions, has a clear hierarchy, and its concepts have to be easily understood and well-represented by considering audience diversity, the breadth and depth of the description, and suitability to school curriculum. Results of field study showed that physics textbooks disseminated in the market and used in secondary schools are very rarely written by secondary school teachers. The finding proves that teachers' skills and abilities in writing teaching materials are very low. Teaching material books written by non-teachers assume that all audiences have similar abilities in understanding the meanings of their writings, and the books are often not contextual.

Thus, there needs to be an action that bridges the expected competence of pre-service teachers and the implementation of the current curriculum for teacher's education in Indonesia, in order to produce good pre-service teachers who have skills in writing teaching materials. The important teaching writing strategies to be developed for pre-service teachers are ones focusing on the improvement of writing teaching material ability and skills, while the writing product is in the form of content presentation of a physics subject matter. The problem frequently experienced by teachers is in translating outline into text. Previous research on the use of concept representation in physics instruction, such as multiple and multimodal concept representations showed that both can improve in-depth understanding of physics concepts. The problem is whether the activity of making written physics concept representations can be used as a medium to improve the pre-service teachers' ability of writing teaching materials using concept representation. Hence, the issue under research is how writing instruction using representational approach embedded in the courses of physics can improve the ability of writing teaching materials for pre-service physics teacher. This is elaborated into the following research questions: 1) Is there any significant difference in the ability of writing teaching materials between students who are treated with representational approach and those treated with expository approach in the teaching and learning?; 2) How does the students' writing teaching material ability improve before and after the treatment of representational approach?; 3) How effective is the treatment of representational approach in improving pre-service teachers' writing teaching material ability?; and 4) How effective is the treatment of representational approach in helping improve pre-service teachers' motivation and self-regulation in writing physics teaching materials? The hypothesis for the first research question is that there is no significant difference in the improvement of the ability to write physics teaching materials between the experimental and control classes.

The significance of this research article is the development of multiple representations and multimodal representations in writing activity, aimed to improve the ability and skills of writing teaching materials

for pre-service teachers. This writing teaching approach is developed to train pre-service teachers in order to have the knowledge and skills of writing teaching materials appropriate to their fields of study by taking advantage of the benefits of multiple concept representations and multimodal representations, as well as improving the ability of representing physics concepts. This representational approach in teaching writing, specifically designed to improve the pre-service teachers' competence of writing teaching materials, has never been previously reported, both in journals and proceedings.

1.1. The Theoretical Framework of Representational Approach

The technique employed by scientists in communicating research results to the scientific society is very appropriate to be used by teachers in teaching the complex and abstract concepts of physics. Scientists write their research reports using various representational modes to be easily understood by other scientists or even people in general. The same is true for natural science teachers who have to be skilled in making representation using various representational modes in order to be understood by their students with diverse backgrounds. The research [5, 6, 7], found that each student has different difficulties in understanding physics concepts represented by a certain mode. A mode of representation refers to a representation structure used in describing content information. A table, graph, and diagram of data can all realize the same information, but their describing behaviours are very different as a result of modality changes. The use of multiple representations in science has been empirically proved to improve in-depth conceptual understanding [8, 9 ,10,11,12,13,14,15]..

Similar to the function of multiple representations, multimodal representation can help students conceptualize and synthesize the relationship among new physical principles with a new way because they process the offered information in various modalities activated by curriculum makers through the combination of representational modes [4,16]. Multimodal representation is a representation of a topic or subject matter by integrating several representational modes into a cohesive writing. Some research on the use of multimodal representation combined with WTL activity in physics instruction has been conducted [17, 18], but the focus was on improving conceptual understanding of the content learned.

The teaching approach of writing teaching materials is developed by improving the ability and skill of representing physics concept gradually and followed by using the skill to write teaching materials. This approach is designed with the following stages: Concept map, types of representational modes, translation among modes of representation, multiple representations, and multimodal representation. Fig. 1.

Concept map is one's understanding of a topic through the mapping of concepts and hierarchical connections among concept, where the more general concepts are placed higher on the map and the same level concepts are grouped together [19]. This concept map stage is used for students' self-reflection so that they can assess themselves on how far their understanding of a subject matter content to write is. By referring to the description of the subject matter they make and the results of their self-reflection, students will realize which concepts or laws from the subject matter they have not

understood well. In addition, the students will test whether the description they make has been hierarchically arranged or not.

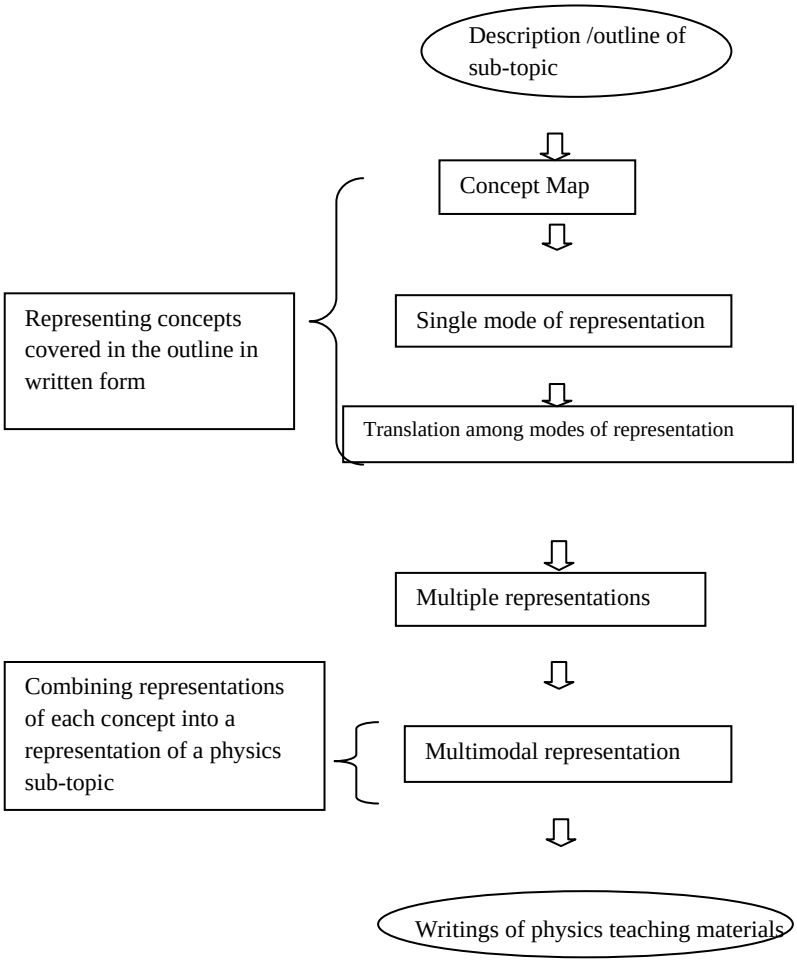

Fig.1 Representational Approach Learning to Write

The essential element of a concept map structure is a proposition consisting of two concepts or more, connected with labelled links. The propositions then branch out, forming a larger structure that provides a general description for: 1) Theory and concept understanding related to the topic; 2) Concept management into sub-concept for each group and category; 3) Understanding relationship of each of the concepts, how they are related to one another; 4) Synthesizing information, ideas, and concepts and seeing the whole picture; 5) Encouraging creativity and developing the skill of higher level thinking and strategies; and 6) Providing feedbacks from teachers for students' misunderstanding and comprehension development from time to time.

Conceptual knowledge in physics is frequently found in an abstract-symbolic form. The symbols in physics have exact meanings and should be combined using the right rules. In contrast, human mind is connected well in pictures, such as a representation emphasizing qualitative features which are not in

detail, even though the information is correct. If we desire students to learn symbolic representation to be used in physics practicum, we have to change the abstract way of describing this world into a more concrete description.

The representation instrument includes, among others, types of representational modes and multiple representations of concept. The types of representational modes are text, mathematic equation, pictorial diagram, bar diagram, picture, free body diagram, diagram scheme (circuit diagram), and the like. The selection of which representation to use depends on the nature of information to be represented. This stage is more of a review on how to make a graph, table, and picture, in relation to representing physics concepts. The special emphasis of this stage is the improvement of students' skills and knowledge in determining which modes of representation are the most appropriate for explaining a concept. The concepts previously mapped attempted by students to be represented in writing by using the representational mode they think as the most appropriate. At this stage, students discuss representation of a concept using certain representational mode, making sure whether the information of the concept has been wholly covered or not. At this stage, students are shown that each representational mode has its limitations. Additional explanation is needed to complete the information covered in the concept.

Multiple representations of concept is defined as explaining the same concept using various types of representational modes. Multiple representations pertain to oral or written science communication capacity in describing the same concept or process using different modes of representation. The ability to represent a concept with various representational modes is a very important competence teachers should master, for teachers will then be able to accommodate students' difficulties in understanding concepts of physics taught both orally and in written form. Using multiple representations means that one representational mode will compensate for the weakness of another representational mode. At this stage, students are assigned to represent each concept listed on the concept map, with a minimal use of two written types of representational modes.

After students are able to translate among different modes of concept representation and make multiple representations of a concept, what follow is the students should have knowledge on how to represent a topic or sub-topic of a teaching material. Included in a topic or sub-topic of physics are different concepts, laws, and principles. To present or represent or re-represent a topic or sub-topic of physics requires knowledge and skill in making multimodal representation. Multimodal representation is explaining a topic or sub-topic by integrating various types of representational modes so that a cohesive writing can be produced. At this stage, students are assigned to represent a topic using outline and an appropriate hierarchy in accordance with the order in the map concept previously made. This is done by combining representations of the previous concepts, both using single representation and multiple representations. Afterwards, a review and editing are done in order to gain writings of teaching materials of a sub-topic that are easily understood by their readers.

2. Method

The research sample consisted of students enrolling in a school physics course (selected topic), consisting of 17 students. The small number was purposively selected in order for the supervision of students' teaching material writings and the implementation of writing control at the review and editing stages to be more effective. The control class consisted of students enrolling in optics and waves course for the same school year, totalling to 27 people. The experimental class was given representational approach embedded in the school physics course with selected topics during the discussion of waves, while the control class was treated with expository approach during the instruction of the topics of waves and optics. In the experimental class, for the topic of waves and optics each student was given a structured task of writing teaching materials for three times. The content of waves and optics was made into 17 sub-topics, and each student wrote a different sub-topic. The writings they made were intended for senior secondary school students. The first writing task was given before treatment, the second one was given to the experimental class students after they received materials on the types of concept representational modes and concept multiple representations. Meanwhile, the third writing task was assigned after the students learned about multimodal representation. Each student's task was assessed using a rubric for the quality of teaching material writing. The rubric for writing assessment was adapted from the rubric for writing evaluation made by Brian Hand et al.[17]. The aspects assessed were: concept correctness and clarity, the adequate selection of mode of representation and its integration into writing, the breadth and depth of the main discussion, the conceptual hierarchy and writing organization, the clarity of main idea explanation in writing, the compliance to punctuation and writing rules, and the ability to influence audiences in writing.

On the other hand, students' motivation and self-regulation in writing teaching materials were measured twice, namely before and after treatment. The instrument used to measure motivation and self-regulation was Test of Self-regulation (MSLQ) based on and adapted from [20]: A manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ).

The data were analysed statistically, where to test the difference The Kruskal–Wallis statistic test [21] was used, and to determine the level of writing ability the percentage of normalized average gain was used; the results were then interpreted using Hake's criteria [22]. Meanwhile, to determine the effectiveness, the treatment was analysed using effect size. The formula used to calculate effect size was the one formulated by Coe [23] and was interpreted using Cohen' criteria [24].

3. Findings

The hypothesis test was done employing The Kruskal-Wallis non-parametric statistical test. Analysis results showed that H_{cal} = 22.77. The value was compared to H_{critic} in the distribution table of Chi Square ($\chi 2$) at a degree of freedom (df) = 1, for α = 0.005, namely H_{critic} = 7.88. Based on the data, it was found that $H_{cal} > H_{critic}$ which means that H_0 was rejected. The results showed that there was a significant difference in the ability of writing teaching materials between students treated with representational approach and those treated with expository approach.

The improvement in the ability of writing teaching materials among students treated with representational approach was determined by calculating the normalized gain between the writing products of the first, second, and third assignments. The mean percentage of the students' ability in writing teaching materials before treatment was 42.6. Meanwhile, the percentage of the students' ability in writing teaching materials in the midst of treatment, namely after they were given knowledge on types of concept representational modes and multiple representations was 75. Finally, the percentage of the students' ability in writing teaching materials after learning and practicing using multimodal representation was 83. The mean percentage of the normalized gain between the first and third writing assignments was $\langle g \rangle = 0.704$ or $\% \langle g \rangle \equiv 70.4$ with a high criterion, between the second and third writing assignments was $\langle g \rangle = 031$ or $\% \langle g \rangle = 31$ with a moderate criterion, and between the first and second assignments was $\% \langle g \rangle = 56$ with a moderate criterion.

The effectiveness of representational strategies in improving the ability of writing teaching materials between the experimental and control classes was determined by calculating effect size. Based on the analysis results, the corrected effect size obtained was $d \equiv 1.89$, which is categorized as high according to Cohens' criteria. Hence, the treatment of representational approach had a high effectiveness in improving the ability of pre-service physics teachers in writing teaching materials.

The effect size of representational strategies in helping improve pre-service teachers' motivation and self-regulation to write physics teaching materials was $d \equiv 0.77$, which was categorized as moderate according to Cohens' criteria. Thus, the treatment of representational approach had a moderate effectiveness in improving pre-service physics teachers' motivation and self-regulation in writing teaching materials.

4. Discussion

The students received an instruction using representational approach were aware that the concepts of physics to be taught to students should be correct, free of misconception, and explained clearly. The awareness was shown by the quality of teaching material writing made for the main idea of waves, where 64.7% of the students fulfilled the criterion that all concepts or laws of physics covered in the explanation of the main subject matter or sub-topic were correct and clear. The similar writing task made by students in the course of waves and optics (control class) showed that only 5.6% of the students' writings had the quality that fulfilled the elements of correctness and clarity of all the concepts explained in their writings.

The characteristics of representational approach that encouraged students' ability in writing teaching materials in this research, whose influence triggered awareness that physics concepts or laws covered in the main subject matter to be written should be correct and clear could emerge in the stages of: Concept mapping, types of representational modes, multiple representation making, and translation among modes of representation. When students make their map concept of a main topic or sub-topic, they are simultaneously reflecting on how far they know about the topic. The activity done in this stage

is students write all the concepts covered in the subject matter to be written. Next, the concepts need to be mapped into a diagram where students have to arrange them from the most general to the most specific vertically. With that condition, students are obliged to reread the subject matter, both from textbooks and lecture notes that they have made. Students should pay attention to the descriptions of the content covered in the subject matter and its hierarchy.

The following activity is for the pre-service teachers to represent the concepts covered in the main topic, whose hierarchy has been stated in the concept map. The task done by students in this activity is how to represent physics concepts to the audience, namely senior secondary school students. Therefore, students should first of all learn the types of modes of representation, trying to represent one concept with a single mode of representation. The student teachers are conditioned to begin to be aware that their future students will have different backgrounds. Hence, pre-service teachers should have the capability to determine the most appropriate type of representational mode to be used in explaining concept so that the majority of students can understand it. Nevertheless, the problem most frequently faced by student teachers in writing teaching materials is to explain concepts covered in the subject matter they write using their own sentence arrangement. The concept is correct, but because the sentence arrangement is not adequate, it becomes unclear.

The writing quality of physics teaching material, in addition that the concepts, laws, and principles of physics covered should be free of mistakes or misconceptions, has to be able to provide ease for the audience to understand the content. The majority of pre-service teachers who were treated with representational approach showed their abilities in using multimodal representation in the making of teaching materials. From the teaching material writings assigned on the topic of waves, 64.7% fulfilled the following criteria: 1) The physics concepts or laws covered in the main/sub-topic were represented using multiple representations (text, picture, graph, table, mathematic equation, chart), so that the topic explained in the writing was more easily understood; 2) The various modes of representation used to represent the concepts or laws were integrated into a mutually completing unity, where synergy between types of representational modes was achieved, making it easier for the audience to understand the content; and 3) The order of types of representational modes selected was appropriate to the concepts or laws of physics represented. The knowledge on the use of multimodal representation in writing teaching materials had been successfully applied by the majority of students in the experimental class. They used three or more representational modes to make written teaching materials from one topic of waves. The orders of the use of multimodal representation were varied, but the student teachers always began with explaining the subject matter using a mode of representation of text or narration. The pre-service teachers had attempted to integrate various modes of representation into their writing of teaching materials in order to be a wholeness, namely by means of adding another mode of representation if the concept explanation with a certain representational mode was thought to be less clear for the audience, and each mode (picture, graph, diagram) used in writing teaching materials was described in the mode of text and then clarified. The competence that most student teachers had not sufficiently understood was the integration of the representational mode of mathematic equation into their writings. The majority of mathematic equation mode used in their teaching material

writings for a subject matter still appeared to be separate or unintegrated. The mathematic equation written was not further explained by the help of other representational modes, such as text, to help the audience understand more easily the meaning of the equation. This is indeed the difficulty experienced by most novice writers of teaching materials, which can be caused by a lack of understanding of the concept or the difficulty in translating the mathematic mode into another representational mode.

The ability of writing teaching materials of the student teachers who were treated with representational approach was highly in contrast to that of the students in the control class seen from their writings during the course of waves and optics, where none (0%) of control class students' teaching material writings fulfilled the criteria. The writings of teaching materials made by control class students mostly used two or more representational modes. The difference in the quality of teaching material writings was apparent in that the representational mode of picture or graph used was merely an accessory or complementary, even sometimes the picture inserted did not have any association with the discussed topic. Even though the representational modes were appropriate for the selected subject matter discussed, the modes seem to be separate or unintegrated into a whole and mutually completing unity. The small number of the teaching material writings made by students of the control class only used one representational mode, namely text or narration mode.

The criteria for quality teaching material writing are also determined by the adequacy of the breadth and depth of the subject matter or sub-topic explained. Research data showed that there was a difference in the ability of writing teaching materials considered from their depth and breadth between experimental and control classes. 76.6% of the experimental class' teaching material writings and 0% of the control class' had adequate breadth and depth, respectively. The students treated with representational approach in the preparation stage gained knowledge about senior secondary school curriculum and the standard competence for graduates in the subject of physics. This knowledge was what made the writings of teaching materials made by students treated with representational approach showed a better quality in terms of their breadth and depth compared to those made by students in the control class.

When a teacher is going to deliver instructional materials, he or she has to prepare the teaching materials in order to be easily understood by students. The teaching materials should be arranged hierarchically, namely from the general to the specific or the reverse. According to the theory of subsumption by Ausubel, teaching students should be started from what they have already known and followed by introducing new concepts. The quality of teaching material writings made by students treated with representational approach showed that 47.1% had a clear conceptual hierarchy; clear proposition used to connect once concept to another; and regular writing organization, moving from the general to the specific and the reverse. This is different from the quality of written teaching materials produced by students in the control class, where their writings for the topic of waves did not fulfilled the criterion (0%). The fact demonstrated that writing teaching materials with a good hierarchy is not an easy job for novice writers.

Representational approach applied to the experimental class facilitated the students to have insights into how to compile teaching materials hierarchically. Those who have succeeded composing description for the main topic of waves are further introduced to the concept mapping. After that, students are assigned to write concepts, principles and laws of physics covered in the subject matter to be written in teaching materials. Next, they have to compile the list of those concepts in the form of a diagram as explained by Novak and Gowin, with a hierarchy from the general to the specific.

The main theme of writing is elaborated into several main ideas. Each main idea is elaborated through explanations or supporting facts and described in one paragraph. The main idea is usually stated in the first of last sentence of each paragraph. The same is true for the writing of physics teaching materials, writers should be able to express clearly the concepts relevant to the subject matter. The clarity of a concept description in written teaching materials can be seen from the existence of questions probably asked by readers pertaining to the explanation of the concepts that the readers cannot find in the teaching material writing. The fewer questions asked by readers, the better the quality of the writing reviewed from its clarity, and the reverse is true: The more questions asked by the readers, the less the quality of the writing from the aspect of its clarity. The quality of teaching material writings in terms of its clarity in expressing the main ideas and their supporting concepts made by the experimental class showed that 76.5% of the students had been able to express their thoughts and concepts clearly, and the thoughts and concepts were relevant to the main idea or plot, so that readers could understand more easily the topic, concepts, and main ideas; in other words, they were not left with important, unanswered questions.

Writers of teaching materials attempt to build communication with their audiences by certain means. The communication can be built through questions, invitation to do something related to the content taught, suggestions to observe phenomena around them pertaining to the subject matter explained, and the like. Writers' communication with their audiences in writing can also be established through representational approach designed to encourage the audiences to think of a problem or a cause of a phenomenon, and finally the writers guide the audiences to draw a conclusion. The quality of teaching material writing produced by students in this research as novice writers almost did not fulfil the criterion of being able to influence the audiences by writing teaching materials, which are provocative and designed to encourage the audiences to think, guiding and directing the audiences to draw a satisfactory conclusion. The teaching materials written by students, both in the experimental and control classes in general only once or twice invited and encouraged the reader to think.

The students' motivation and self-regulation in the activity of writing teaching materials inevitably improved because of the stages designed in the representational approach using multimodal representation. The first stage of this instructional program is to provide information and discuss teacher's basic competence pertaining to the professional and social competences. In addition, the importance for one to have the competence of writing teaching materials, both as scientist and teacher, is discussed. As a scientist, a teacher has to also develop his or her teaching strategies by conducting classroom action research, and the results should be put in article or paper. A teacher understands the

diversity of his or her students, so that s/he should be able to provide contextual teaching materials and accommodate the diversity of his or her students. The advantages gained by a pre-service teacher to have the competence of writing teaching materials can be in financial matter and other advantages. The stages of instruction in this research had improved students' motivation in engaging with the lectures, impacting on their seriousness in completing the writing tasks given.

The representational approach was also proven to improve students' self-regulation who attended the course. The improvement was due to the stages of the designed scaffolding and the writing model that allowed for the formation of self-regulated students. The main aspect of self-regulation is metacognition, and that includes planning, monitoring, and activity organization [23]. In this instructional program, each student does the task of writing teaching materials for different sub-topics. In the planning stage, the students should make description of the teaching materials they will write, identify the concepts contained in the subject matter and think about how to represent the concept to be easily understood by readers. The next step is thinking of how to integrate various representational modes selected for each concept so that a cohesive writing of teaching materials can be produced. The activity demands students' independence because the task is given a time limit. Hence, students are forced to develop self-regulation strategies in terms of managing time and learning environment so that the task can be finished on time. The various efforts that can be made are, for example, looking for adequate references, reading the curriculum of senior secondary school, and determining the depth and breadth of the teaching materials to write. If they still feel some difficulties in doing the task, while it has to be finished at a certain time, then students should self-regulate themselves to find learning partners, both their classmates for the same course and other participants of another course who can be invited to discuss the writing of teaching materials from the sub-topic to be written. Students should also be able to find other aids to help them finish the task.

Each student is given an opportunity to present his or her writing before the class, where other students and the lecturer provide feedback and input. The students who present their writings should be able to control themselves so that all invaluable feedbacks and inputs can be well-noted. Based on the inputs gained, the students should improve their writings; hence, they regulate themselves so that all information still needed to complete their work will be obtained. The various activities helping students to improve their self-regulation will be further strengthened in the next task of writing teaching materials for a different sub-topic. Thus, the various activities done in the representational approach in this research had a contribution in improving students' motivation and self-regulation.

5. Conclusion

Based on data analysis, it can be inferred that multimodal representational approach has allowed for an improvement in the ability of writing teaching materials among pre-service physics teachers. The finding is strengthened by the following analysis results: 1) There was a significant difference in the ability of writing teaching materials between students treated with representational approach and those treated with expository approach; 2) The ability of writing teaching materials among students treated

with representational approach improved with a percentage of the average normalized gain that was considered at a high-level criterion; 3) The treatment of representational approach was effective in improving the ability of writing teaching materials among pre-service physics teachers with an effect size that was categorized as high; and 4) The treatment of representational approach was effective in improving students' motivation and self-regulation in writing teaching materials, that was classified as having a high-level criterion. The characteristics of the representational approach allowed for embedment in various subject courses in the field of physics, so that writing across curriculum can be shaped to improve the ability of writing teaching materials among pre-service teachers.

This study also indicates the need for further research in following areas: the influence understanding physics concept on the quality of writing teaching materials produced, the influence of motivation and self-regulated learning writing teaching materials programs on student's perception and perspective, and the effectiveness of each stage of the representation approach in improving writing skills teacher candidates teaching materials.

In terms of the implication for how lecturers embed representational approach to support pre-service physics teachers to have the ability of writing teaching materials, the findings of the research recommend that there should be a conditioning of teaching and learning process that encourages students to make a concept map for each of the subject matters they study, re-represent physics concepts using multiple representations, and represent a subject matter in writing using multimodal representation. It is very important to show the pre-service teachers the various school environments and students' neighbourhoods, to learn the diverse backgrounds of students as references for their teaching material writings in order to be contextual and accommodating for various students' backgrounds. The job requires sufficient additional time in addition to the face-to-face classroom lesson, both for the students and lecturers. Additional time for lecturers is needed in the process of controlling students' writing tasks, namely in the stage of reviewing and editing writing.

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