Translation among modes of representation by pre-service physics teacher on magnetic force on particle concept

W Handayani¹, W Setiawan¹,², P Sinaga¹,³ and A Suhandi¹,³

¹Sekolah Pascasarjana, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudhi No. 229, Bandung 40154, Indonesia
²Departemen Pendidikan Ilmu Komputer, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudhi No. 229, Bandung 40154, Indonesia
³Departemen Pendidikan Fisika, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudhi No. 229, Bandung 40154, Indonesia
⁴Program Studi Pendidikan Fisika, Fakultas Tarbiyah dan Keguruan UIN Sunan Gunung Djati Bandung, Jl. A.H Nasution No. 105 Bandung, Indonesia

*wahyuni_han@student.upi.edu

Abstract. In the 21st century, communication skills are the core of some competences required in a globalized world. Communication skills encompass the ability to speak and write confidently and to handle complex multi-mode information. For effective teaching a teacher need to be highly skilled in all these generic skills areas. In physics, more than only one representational format is often used to convey information and support knowledge construction. Pre-service physics teachers often find these use of representations both verbal and visual, and the translation between them difficult. This study was aimed at investigating translation among modes of representation skills of the pre-service physics teachers. The study involved 36 pre-service physics teachers. A test was constructed to measure their skills in translation among modes of representation. In this test, pre-service physics teachers were asked to explain concept in magnetic force on a particle. This finding support the necessity of developing skill of pre-service physics teachers in translation among modes of representation as a part of communication skills.

1. Introduction
In the 21st century, communication skills are some of the core competences required in a globalized world. These skills encompass the ability to speak and write confidently and to handle complex multimodal information [1]. Working in the field of multimodal tends to be oriented to a detailed description of speech, writing, movement and action, and the visuals, and descriptions of their interactions in communication ensembles and their use in science classroom [2]. Other modalities than the verbal are also involved in science educational texts and they are becoming more prominent [3].

Teaching are not easy as it seems, since tutors should not only know subjects and disciplines perfectly but also be capable of seeing and understanding students’ needs and preferences. Every teacher should be conscious that students, for many reasons, have vastly different learning styles, teacher should to know various methods on how to make lessons productive and interesting regarding different students’ attitudes and approaches. A good physics teacher is someone who realizes that among the most valued and significant roles of a science teacher is to help a student understand a body of information and the
processes of scientific investigation. When students have difficulty in understanding a physics concept, then the task of a teacher is to help students to have a deep understanding of the concept. Physics teachers should be fluent in making representation using various representational modes in order to be understood by their students with diverse backgrounds. It has been argued by many researchers that, in order for students to gain meaningful access to physics knowledge, they need to develop competence in the various representational formats used in physics [4]. Effective and efficient communication should be established between the teacher and the student in the learning-teaching process. Therefore, effective teachers are also regarded as effective communicators [5].

A review of the research in the fields of language and education shows that representation is defined as a type of transformation or change of information obtained through the conceptualization, visualization, or concretization of an item in a certain format or mode [6]. Modes are displays (pictures, graphs, text, tables, diagrams, or animations) used to describe information. 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. Modes in representations have different strengths and weaknesses in terms of accuracy, clarity, and associative meaning [6]. Someone who use mode representations in communication easily contextualize the content to be communicated semiotically [6]. The use of mode representations consisting of two or more modes and transferring between them brings many advantages to learning. Waldrip et al, suggested that students who recognize the relations between different modes perform better in conceptual learning than those who do not [7]. Ainsworth et al have pointed out that successful learning with multiple representations involved the ability to translate information between representations [8].

Translation is a process in which constructs of one modes of representation are mapped onto those of another. The selection of which modes of representation (mathematic equation, picture, bar diagram, pictorial diagram, free body diagram and scheme diagram), that will be used depends on the nature of information to be represented. Translation among different modes of representation is an important skills that to be mastered by pre-service teachers because they will face students with diverse abilities in catching and understanding information, both on transmitted orally and in written. Pre-service teachers have to be skilled in translating between modes of concept representation to accommodate students’ difficulties in understanding physics concepts.

The research by Hwang and Roth showed an extremely important role of translation among modes of representation in the realisation of communications between a teacher and students during classes [9]. In the “one way” communication Becker et al. also pointed out the importance of translation among modes of representation during a whole class discussion [10]. They also emphasised the importance of the teacher in promoting translation among modes of representation in such circumstances.

In this study, we investigated the extent to which pre service physics teacher were able to transform from representation modes of mathematic equation to representation modes of picture. In this task pre service physics teacher were asked to make the transitional representation or intermediary representation namely text (narration) mode [11].

2. Method
This study employed descriptive method to explore pre-service physics teachers’ skills on translation among modes of representation on Electricity and Magnetism on topic of magnetic force on particle. The participants of the study were 36 undergraduate students ranging in age from 19 to 22 years who were taking Electricity and Magnetism courses in the fifth semester of the third year at Physics Education of a college in Bandung. The instruments used in this study were written tests. The written test asked student to translation representation mode of mathematic equation: \( \vec{F} = q(\vec{v} \times \vec{B}) \) to the representation mode of picture. The translation skill among representation modes aims to test the translation skills of pre-service physics students from the origin mode to the target mode requiring the intermediary representation. The answer of the pre-service physics teacher to each of the
representational skills was analyzed in conformity with the rules of representation in the Electric-Magnet concept commonly used in University Physics textbooks.

3. Result and discussion

3.1. Translate to representation mode of text

The concept of Coulomb’s Law in the academic curriculum of Physics is available in Fundamental Physics and Electricity and Magnetism courses. Pre-service physics teacher who involved in this study is the third year students, in their memory already have the concept of magnetic force on a particle. The concept is stored in their memory as internal representations (i.e. interpretations) are knowledge and structure in their memory [12, 13]. The translation from representation mode of mathematic equation into representation mode of picture required a mediator, namely the representation mode of texts. This task is designed to allow pre-service physics teacher to explain a scenario in which their personal understanding is presented to non-expert reader. Mathematics, as a formal science, does not care about the ‘truth’ of its propositions, but about the validity of the logical procedures that relate them. In Physics, on the other hand, it being a factual science, all enunciation has a meaning [14].

Translating from the representation mode of mathematic equation to the representation mode of texts (narration), requires student to analysed first the equation, in terms of the relationship between parameters the equation contains. What follows is determining what to describe from the concept of physics law that stated in the mathematic equation. The student must recognize the symbols used in the equation. In this study the mathematical equations that must be represented in text mode is $\mathbf{F} = q (\mathbf{v} \times \mathbf{B})$.

Based on the analysis of pre-service physics teachers’ answer, there are some insufficiency in representing text mode, among others: 1) 27% the pre-service physics teacher misunderstood the “$\mathbf{v}$” symbol, which he/she understands as an electric potential difference that should “$\mathbf{v}$” denotes velocity (Figure 1), 2) 33% students write the relationship between the magnitudes contained in the equation in sentences form, they did not make any explanation of the modes of mathematical equations into text modes (narration), and 3) 90% the narratives expressed by the students have not fully explained the concepts meant by the mathematical equations mode, students did not distinguish the direction of force for the type of charge, whether the charge is positive or negative, and students did not distinguish between the magnitude and the direction of force, in this case the force is the vector quantity and the direction of the magnetic force is always perpendicular to the direction of the magnetic field as well as the direction of velocity, but the magnetic force is proportional to sin $\theta$.

The condition shows that pre-service physics teacher were not trained to translate representation modes of mathematical equation to representation mode of text. Representation mode of text is an important element to contextualizing mathematics equations so that the information familiar to students’ lives. To be a successful physics teacher it is not enough to be able to identify the physics quantities in the equation and know how to use the equation to solve physics problems. Physics teacher have to be able to make explanatory of mathematical reasoning in physics so that students would increase their awareness about the nature of physics and the role of mathematics. The meaning of mathematic representation must be made explicit when introducing young students they must understand and internalize the fact that the ‘formulas’ of physics, contrary to what is found in logic or mathematics, are interpreted formulas [14].
3.2. **Translation to representation mode of picture**

After pre-service physics teachers perform the translation from representation mode of mathematical equations to the representation mode of text, the next step they make the target mode namely the representation mode of picture. This representation mode of picture should be made in such a way that the audience can understand how one parameter connects to the other. The process needs cognitive engagement from the students, namely the understanding of the physics concept to be represented. If the concept is not grasped, it will be difficult to determine what to describe or illustrate from the concept.

Representation modes of picture should be covered entirely representation of: 1) source of magnetic field $\mathbf{B}$, 2) vector expression of cross product $\mathbf{v} \times \mathbf{B}$, 3) right-hand rule and 4) the direction of magnetic force for negative and positive charge in the case of due to the presence of a magnetic field. Representations were made by pre-service physics teachers in the representation modes of picture among others: 1) 41% students who draw magnetic field in terms of magnetic poles did not equip by describing the direction of $\mathbf{F}$, $\mathbf{v}$, and $\mathbf{B}$, (Figure 2), but 42% student who draw magnetic field in terms of magnetic field line they can describing the direction of $\mathbf{F}$, $\mathbf{v}$, and $\mathbf{B}$ (Figure 3), 2) no one of pre-service physics teacher represented mode of picture the cross product of $\mathbf{v} \times \mathbf{B}$, 3) all of students who presented right-hand rule (36%), sign charge of particle (q) using I (current) (Figure 4), 4) 92% students did not distinguish the type of electric charges that experience the force so there are no representation mode of picture that distinguish between negative charges and positive charges (Figure 5), and 5) No one who made representation mode of picture covered entirely cross product, right-hand rule and consider direction of $\mathbf{F}$ related to type of charge.

*Figure 1.* Pre-service physics teachers’ answer representation modes of text.

*Figure 2.* Pre-service physics teachers’ representation modes of picture in terms of magnetic poles.
Based on the figure 2 it can be said that when the textbook discussed or the teacher explained magnetism in terms of field lines and magnetic poles are no longer explicitly discussed there will be difficult for student to represent the relation of $\vec{F}$, $\vec{v}$, and $\vec{B}$ especially when the presence of magnetism is represented in term of magnetic poles. In fact, in the course textbook field lines are used to represent the presence of a magnetic field much more frequently than magnetic poles [15]. Students might have been more familiar with the magnetic field line representation.

Figure 4 shows that that pre-service physics teachers’ confusion the concept about the single moving charge and the current in a wire. Figure 5 Shows that pre-service physics teachers’ representation did
not distinguish the type of electric charge that experiences the force so there are no representation mode of picture that distinguish between negative charges and positive charges. This condition in line with the representation modes of text (narration) that students have stated before.

Student difficulties with determining the direction of the magnetic force is the necessity of using the unfamiliar and abstract operation of the vector cross product. The resulting magnetic force vector is perpendicular to the field and velocity of the particle, a direction both unexpected and unintuitive for the novice [15]. Mathematics is understood as a method of problem solving but not as a constructive thinking tool with a physical interpretation [16].

For teachers translation among modes of representation skills have to be mastered and they should move smoothly between various representations because he/she will teach a new concept to his/her students. Therefore, learning about new concepts cannot be separated from learning about how to represent these concepts as well as what representation used mean in the world [6]. Lemke has noticed that to understand and use a scientific concept, someone has to be able to translate back and forth among representation of the concept [17]. This implies that all attempts by teacher to understand concepts in science entail representational work [6]. Using representation has been referred to as the (meta) representational competence [12]. Better representational abilities correspond to better scientific understanding and working with representation can have distinct metacognitive character, which he denoted as meta-visualization skills [18]. Generally speaking, the concept of translation among modes of representation is an important aspect of the representational competence. It is at the core of medium and higher levels of abilities which constitute representational competence [12].

4. Conclusion
Pre-service teachers have to be skilled in translating among modes of representation to accommodate students’ difficulties in understanding physics concepts. To ensure that pre-service physics teacher develop sufficient representational competence during their undergraduate studies is the responsibility of the physics department. There is a range of possible strategies to overcome a lack of students’ representational skill and how these strategies are put into practice in facilitate physics lecturers’ efforts to transform the teaching of physics in ways that better match the needs of today’s students.

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