Where do the Instructional Practices Should be Addressed Aligning to the Twenty-first Century Demands?

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***Abstract*: The emergence of initiatives to improve quality of teaching-learning process in 21th century should be mainly used to guide the instructors which might impact the learning outcome in present day students and how any subject matter should be taught in the future aligning to learning goals. This paper provides brief review of cluster of education research, a concrete definition of teaching pedagogies, and an exemplar of physics instructional intervention developed by using metacognitive strategy integrated with learning transfer of mathematics knowledge.**

***Keywords*: skills for 21th century, intervention, challenges in learning, clusters of instructional intervention, teaching pedagogy practice**

I. INTRODUCTION

Education is the primary service provided by a government or society to prepare its future generation workforce. Therefore, one of the goals of education should meet the demands of the changing world. National Research Council of United States (2012), for instance, confirmed that knowledge and skills in the 21th century must be transferably developed for students' life and work. Educators are required to focus their efforts on the learners' needs, not only to deliver effective teaching-learning approaches. The instructional practices should also continuously align to the education goals of the times. These aims emphasize to transition from over content-based drilling and memorization towards fostering higher-order Although the work environment and information technology is now rapidly changing, however the numerous issues regarding teaching strategy to solve problems, conceptual change, interdisciplinary knowledge, transfer of learning (Kohl and Finkelstein, 2006; Robello et al.,2015) and interest in learning physics (Hidi et al., 2004; Hadzigeorgiou, 2017) remain a core and current emphasis in the learning of conceptual understanding and problem solving (Kwok, 2018). Study of Kohl and Finkelstein (2006), for instance, concluded that the use of mathematical, pictorial, graphical and expressive presentations of mathematics knowledge could increase on problem solving skills of students in physics thinking skills including reasoning, creativity, and open problem solving (Koenig et al., 2012).

Teachers must make changes in pedagogy and teaching strategies to align with 21st century learning. Kumar and Chander as cited in Wei & Othman (2017) argued that 21st century pedagogy was (i) problem solving; (ii) proficiency in high-level thinking; (iii) collaborative; (iv) technology; (v) reflection; (vi) fostering technological skills, information and media; (vii) "Project based learning" and (viii) appraisal as shown in Figure 1.

Saavedra and Opfer (2012) suggested nine principles to teach 21st century skills: (1) make learning relevant to 'big picture'; (2) teaching with discipline; (3) developing lower and higher thinking skills to encourage understanding in different contexts; (4) encourage the transfer of learning; (5) teach how to 'learn to learn' or metacognition; (6) correct misunderstanding directly; (7) promoting teamwork; (8) utilizing technology to support learning; and (9) increasing student creativity.

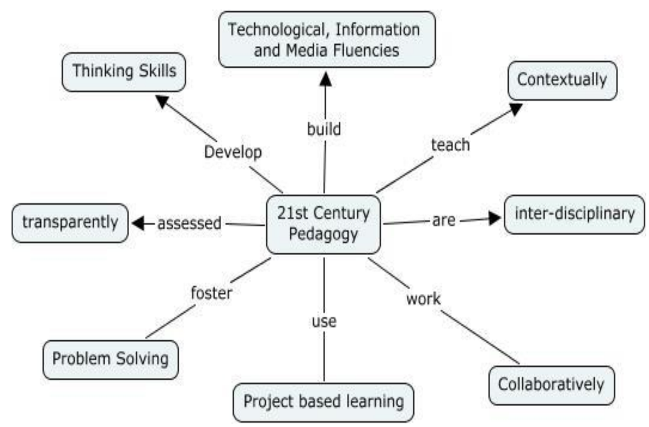

Figure 1. Teaching Pedadogy 21st Century
(Kumar and Chander cited in Wei & Othman, 2017)

Shute et al.(2016) confirmed that the need and requirement in 21st century of learning goals is to enhance learners' skills to solve problems. Physics is absolutely ascertained as a potential tool for developing problem solving skills of the learners (Adachi & Willoughby, 2013; Ince, 2018) through metacognitive thinking (Abromitis, 2009). Moreover, in the curriculum 2013 of Indonesia also confirmed that metacognitive thinking skills should be acquired by senior high school students after having received any discipline learning process (Kemendikbud, 2013).

In association with the learning interest, (Haussler & Hoffmann, 2003; Hoffmann, 2002) argued that there are two major problems faced by educators worldwide i.e the decline of students' interest in learning and decrease of students learning outcomes, physics in particular. Trumper (2006) reported the enrollment of students in high school physics over the last two decades indicate a persistent decline e.g UK, Australia, Japan, USA, and European Union. Haussler & Hoffmann (2003) reported that many senior high school students in many countries avoided the subject or course, showed a negative attitude toward physics which leads to lack of interest. Study of National Center for Education Statistics in 1984 (as cited Mallory, 2004) revealed that only 3.9 % of American ninth grade students will continue their education to get degree in physics or in a science-related discipline.

National Education Ministry of Indonesia reported that from 1.812.035 students of Senior High School Students who have followed the National Final Examination (*UAN*) in 2017, only 758.067 (41,8%) students who choose science major e.g physics, chemistry, and biology (National Education Ministry of Indonesia, 2017). It means that only about 14% students who choose physics as the examination subject. Moreover, Indonesia's average-score of 15-year-olds students in science is 403 which stand for in basic or low proficiency category and its ranking is 62 of the 72 participating countries (PISA, 2015). The lack of students' achievements indicates the lack of students interest in science and is more likely to acute for physics education.

Substantially, education goal initiatives for twenty-first century provide an important guidance to educators for anticipating essential skills and needs for future learners. However, concrete definition of any instructional interventions in schools which adapted to the constraints of learning environment (Reimers & Chung, 2016) and could be implemented to education systems (National Research Council, 2012) had been not much investigated. The instructional interventions concerned with enhancing problem solving capability, promoting conceptual change, cultivating student interest, and developing creativity are still crucial educational issues of physics in many countries. This briefly literature review provides amount of viewpoints regarding cluster of physics education research, practice of teaching pedagogy, and an exemplar of problem solving model which integrating metacognitive strategies with learning transfer of mathematics knowledge in order to develop a sucessful teaching and learning of any discipline.

II. THE CLUSTERS OF INSTRUCTIONAL INTERVENTION IN TEACHING-LEARNING PROCESS

An instructional intervention is aimed at academics. It is not a strategy but learning activity consist of steps to help learners improve at subjects matters or discipline. It is designed to improve learner's competencies by using a certain method, model, or strategy (Lynch, 2019). Nowadays students worldwide encounter a multitude of challenges such that teachers must proactively learn how to recognize academic need. Effective academic (instructional) intervention is potential for identifying students' weakness concepts and skills as well as helping them increase academic competency.

In compliance with the initiatives on advancing twenty-first century education focus on skills as mentioned Bao & Koenig (2019), instructional intervention in the teaching-learning process concern on three broad clusters: cognitive, interpersonal, and intrapersonal. Within the cognitive domain, multiple important competencies have been developed including deep learning, non-routine problem solving, critical thinking, computational and information literacy, reasoning and argumentation, and innovation (Bao et al., 2018) which highly connected with the decision making, creative thinking, and metacognition. Various definitions in the literature for critical thinking is extensively discussed. Ennis 1990 (as cited Bao & Koenig, 2019) defined that critical thinking is the application of the cognitive skills and strategies that goal for and support evidence-based decision making. It is the thinking involved in solving problems, formulating inferences, calculating likelihoods, and making decisions. According to Bao et al.(2018), scientific reasoning includes the thinking and reasoning skills involved in inquiry, experimentation, evidence evaluation, inference and argument that support the formation and modification of concepts and theories about the natural world; such as the ability to systematically explore a problem, formulate and test hypotheses, manipulate and isolate variables, and observe and evaluate consequences.

Critical thinking and scientific reasoning emphasize evidence-based decision making in causal conditions. Critical thinking can be promoted through the development of scientific reasoning, which includes student ability to reach a conclusion after identifying a question, formulating hypotheses, gathering relevant data, and logically testing and evaluating the hypothesis. In this context, both can be characterized as a cognitive domain of instructional intervention (Bao & Koenig, 2019) which involve the process of cognitive and metacognitive thinking. Therefore, until now there is a great deal of research on the importance of student development of thinking process skills which have been found to positively correlate with achievement and success on transfer of learning (Jensen & Lawson, 2011).

Unfortunately, previous research has shown that college physics students are lacking in scientific reasoning. Koenig, Schen, & Bao (2012) reported that a number of 50% students are not capable of applying scientific reasoning in learning. In addition, they has also found that traditional courses do not significantly develop these abilities, with pre-to-post-test gains of 1%–2%, while inquiry-based courses have gains around 7%. A large amount of international study argued that learning of physics content knowledge with traditional teaching practices does not improve students' scientific reasoning skills (Bao et al., 2018). However, endeavors to develope scientific reasoning skills, students' critical thinking, open-ended problem-solving abilities, and decision-making skills are a foundamental curricular objective (Fabby & Koenig, 2013) which aligned with the learning goals of physics in twenty-first century education.

Interpersonal skills are very important to support to the ability to work creatively and collaboratively in the learning process. Interpersonal skills, such as communication and collaboration, are essential for twenty-first century problem-solving tasks, which are often open-ended, complex, and team-based (Bao & Koenig (2019). As a human live becomes more connected in a multitude of dimensions, solving problems often goes beyond the individual. The students must be able to work with others who are culturally diverse backgrounds. Interpersonal skills can be promoted by integrating group-learning i.e. cooperative or collaborative learning model. The learning activities should be designed such that students must work collaboratively and responsibly in teams to find solutions. After discussing and writing scientific reports, final activity is presenting the result (Koenig et al., 2019). By using these models, students are provided with opportunity to engage in open-ended tasks with a team of peers who may have alternatives or more plausible solutions. They also engage in expressing their thoughts and ideas in a variety of context.

Intrapersonal skills are based on the individual and include the ability to manage one's behavior and emotions to achieve goals. Intrapersonal skills reside within the individual and include metacognitive thinking, adaptability, and self-management learning (Bao & Koenig, 2019). One of the perspectives settled on a fundamental mechanism of teaching and learning suggests that knowledge is developed within a learner through constructive processes. Team-based guided scientific inquiry is assumed as an effective method for promoting deep learning of content knowledge as well as developing cognitive abilities, such as scientific reasoning. Emerging technology and methods should serve to facilitate (not to replace) such learning by providing more effective education settings and conveniently accessible resources. However, the vast amount of studies on interpersonal and intrapersonal skills in order to keep the main focus on the cognitive and metacognitive dimension of skills in learning are still challenging in physics education.

III. THE 21TH CENTURY TEACHING PEDAGOGY PRACTICE

In much of the world, the dominant approach model in the learning is still the "transmission" model. Teachers transmit factual and conceptual knowledge to students through lectures and textbooks. The model is hard to shift in education system because it demands less disciplinary and pedagogical expertise from teachers. In gaining skills and knowledge students do not have much learning experience and practice applying the skill to new contexts, communicating it in complex ways, using it to solve problems, or using it as a pivotal medium to develop creativity. Therefore, rote memorization is not the most effective teaching pedagogy to promote 21st century skills (Saavedra & Opfer, 2012).

Based on the previous relevant researches and several point of views had been cited in this paper, the points of teaching pedagogy in the physics learning can be addressed to essential learning needs and skills of the 21st century skills described as follows:

A. Teach the subject matters relevant to student need

Any subject matter designed by instructors should be relevant to student lives. It is not rational to prepare future students only by memorizing of factual knowledge of any subject matter. Overemphasize on rote memorization leads to lack of fruitfulness of learning which in turn leads to disinterested in learning. Teachers need to link any teaching material to another discipline and match it to human enterprises such that it is relevant to their need in society. Students are more likely to makes learning feel more interesting and meaningful. They more realize that the conceptual knowledge they have learned is crucial for supporting their daily live.

B. Use problem solving strategy to enhance thinking skills

Nowadays education aims worldwide is to improve learners' skills to solve problems. Problem solving is assumed one of the 21st century's skills, needs, and universal requirements (Shute et al., 2016). In the curriculum 2013 of Indonesia confirmed that problem solving requires thinking skills incorporated in any discipline learning process (Kemendikbud, 2013). The task of educators is to acknowledge, cultivate, exploit, and enhance the metacognitive capabilities of all learners (Abromitis, 2009). Teaching problem solving is one of the most important topics of physics education (Dorgu, 2015; Ince, 2018), Physics is ascertained be a potential tool to develop problem solving skills of the learners (Adachi & Willoughby, 2013).

For most teachers, the use of instructional intervention to increase students' thinking skills tends to be unclear task. To develop thingking process skills, teacher must be able to recognize or differentiate the features of lower-order and high-order thinking skills. In addition, how to develop the thinking process skills to any learning contexts that related to the demands 21th century is quite difficult. The ability must operationalize in terms of learning objectives aligned to cognitive domains. Open-ended tasks and problem solving problems are potential to cultivate these skills. However, it is long term process. An effort to comprehend the conceptual understandings should be undertaken initially before developing a continuous improvement of thinking skills.

C. Encourage transfer of learning

Transfer of learning also tends to be very difficult as well as challenging for most teachers. Students must apply what they learn in school to other areas of their lives. According to Saavedra & Opfer (2012), there are two types of transfer teachers can encourage namely low- and high-road transfer. The low-transfer can be encouraged by using methods like; (a) provide learning actvities such that the knowledge and skills they have learned could apply to a similar to situation; (b) use talking aloud procedure or verbal protocol through solving a problem so that students recognize the thinking process they might apply to a similar problem. To encourage high transfer, teachers can use another methods like (a) remind previous a particular skill, attitude, concept, etc. students have learned in such ways so that the skills could be applyed to another situation; (b) identify the similar and different properties between analog and target concept.

Robello et al. (2015) confirmed that transfer of learning as a dynamic creation of associations by the learner in a new problem situation. Spesifically, transfer of learning of mathematics knowledges is the process of linking and using mathematics knowledges (facts, concepts, principles, and procedures) related physics problems through the process of horisontal-assimilation and/or vertical-accommodation of the schema (cognitive structure) related to physics concepts or problems.

D. Promote students' conceptual change

Students attend classroom for engaging in learning process have had various alternative conceptions for the subject matter. Generally, these conceptions are not consistent to scientific (expert) conceptions and interferring for further learning (Duit & Treagust, 2003; Chiu et al., 2007). A huge amount of previous studies revealed that the misconceptions are resistant to change through a rote learning approach. Many misconceptions still existing after instruction indicates accomodation of student's cognitive structure (Shen et al., 2017). For further meaningful learning to occur, new concepts must be integrated into a learner's existing knowledge structure by linking the new knowledge to already understood concepts. Simply stated, learning physics is a conceptual change process. To be effective teachers can provide learning activities to reduce the misconceptions by integrating them with the teachers' regularly scheduled teaching in the classroom.

E. Engage students in collaborative learning

Collaborative learning is a strategy of learning in which students interact in smaller groups with the goal to find solution of problem collectively (Mattatall & Power, 2014). The strategy is applicable to large extent of physics topics. Student's conceptual understanding could be transferred to another learning context (Mbanefo,2014). As learners collaborate with each other they engage in to clarify any ambiguity, to exchange different ideas and feelings, and to appreciate alternative opinions in the learning process. Moreover, collaborative learning can provide opportunities for students to learn any subject matter through more realistic situation. Anthony et al. (2018) argued that collaborative learning could increase learning motivation and enhance critical thinking skills as well.

F. Develop students' creativity

Creativity is the cognitive ability to produce novel and valuable ideas (Gordon as cited Joyce & Weil, 1987) emphasizes that creativity as a part of our daily work and lives. Like intelligence and learning capacity, creativity is not a fixed characteristic that people either have or do not have. Rather, it is incremental, such that students can learn to be more creative. Training students' creativity can make a significant contribution to the flexibility and ability to handle changes in their lives/work. Incorporating an increase in student creativity in learning objectives and educational curriculum is important. Morten & Vanessa (2007), asserts that every subject in the school should emphasize creativity, on an agenda that reflects its own characteristics. Beaton (in Morten & Vanessa, 2007) argued that creativity as a very important factor for success in school science. With practice and the provision of learning conditions, carefully designed will enable students to produce something "new" and work in accordance with the demands or desires. Creative development requires structure and intentionality from both teachers and students.

G. Use information technology to support learning

Technology offers the potential to provide students with new ways to develop their problem solving, critical thinking, and communication skills, transfer them to different contexts on topics relevant to their lives by using engaging tools. There are some examples of information technology and instructional media teacher can used to support learning e.g internet, e-book, web-based forums, and (real and virtual) laboratory.

The avaiability of internet's sources are countless. By accesing the internet, students can gather a huge amount of information for supporting their learning objectives. Students have an opportunity to filter information they received. Students has also a personal right to determine usefulness of the source. To be digital citizenship in the future lives, students should be guided wisely for accessing the internet and social media as well.

Meltzer & Otero (2015) claimed that for a long time the laboratory has a distinctive role in supporting student outcome. Many existing labs in many schools have received criticism for their outdated worksheets and their cookbook styles. Labs have been mainly used as a tools for investigating the accurateness the formulas or principles in textbooks. In this context, The effectiveness of laboratory in developing student content learning is lacking. Hofstein and Lunetta (1982) as cited Meltzer & Otero (2015) asserted that many previous researches were unable to demonstrate the impact of the lab on students high order thinking skills.

IV. A MODEL OF PHYSICS INSTRUCTIONAL INTERVENTION

Based on the tracing study, it is summarized that some learning interventions to improve the ability of students to solve physics problems had been employed in some previous studies. In addition, a number of previous investigations found that students' problem solving competencies in physics in many countries are low (Ince, 2018). Lack of mathematical skills, inability to apply the concepts and principles of physics properly, and lack of thinking strategies that appropriate to problems are regarded as the major obstacles in solving physics problems (Butler & Coleoni, 2016; Körhasan & Ozcan, 2015; Reddy & Panacharoensawad, 2017). Therefore, a forthcoming physics educational research needs to increase problem solving skills and explore the causes in order to overcome learning difficulties (Kereh et al., 2014; Hwang et al., 2014). It is declared that students who are unable to solve physics problems they faced, they are very likely not able to transfer what they have learned from mathematics to physics (Hollabaugh, 2017; Obafemi & Ogunkunle, 2013; Robello et al., 2015). De Leone and Gire (2005) investigated the influence of non-mathematical presentation on students' problem-solving competencies in physics involved 39 university students. They argued that the students who solved the given physics problems using mathematical expressions showed more appropriate solutions and succesful than those who solved them using without mathematical expressions. It was also recommended in the study that the students with lack of mathematical knowledges need be trained explicitly to solve physics problems through using mathematical expressions (De Leone and Gire as cited Ince, 2018).

Numerous studies of instructional intervention summarized that the use of appropriate problem solving strategies to physics subject matter content could; (1) promote students' conceptual change (Duit& Treagust, 2003; Hwang et al., 2014; (2) cultivate students' situational interest, good attitude, and achievement motivation (Schraw, Flowerday, & Lehman, 2001)**;** (3) make the students feel more confidence, enjoy, and fun (Adachi & Willoughby, 2013; Shute et al., 2019); (4) promote students' self-efficacy and self-regulation; prepare students to be a strategic and independence learner; become students to be a skillful or experienced thinkers (Djudin, 2020); (7) increase the students' mathematics knowledges (Kereh et al., 2014; Robello et al., 2015); (8) increase the student ability to interprete the problems they faced in daily activities more logic and systematic (Doktor et al., 2015); and (9) prepare the students be a good citizen in anticipating the requirements of the future life (Abromitis,2009: Kwok, 2018).

Although it is convinced that mathematics knowledges become a prerequisite for learning physics, however, there are only few studies that investigate the impact of basic mathematics concepts on the ability of physics problem solving. Ellis and Bond (2014) claimed that the use of a specific instructional intervention for improving students' problem solving by using metacognitive strategies in physics is not much investigated. In compliance with a large amount of perspective and studies as mentioned above regarding the importance of problem solving and transfer of learning as considered the crucial skills and requirements for anticipating the 21th century, at the this last section I insipired to develop the model as a medium for instructional intervention as shown in Figure 1.

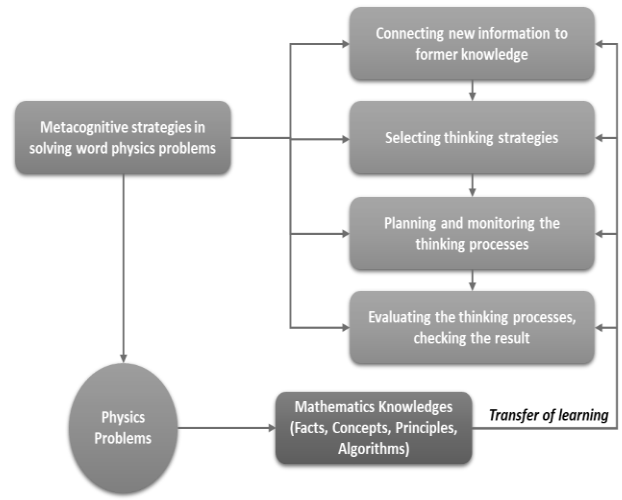

Figure 2: Integration Model of Metacognitive Strategies with Transfer of Learning of Mathematics Knowledges

To execute operationally the instructional intervention of metacognitive strategies integrated with transfer of learning of mathematics knowledges (as shown in Figure 2) in order to solve physics problems, instructors should guide and model intentionally the four syntaxes described as follows:

1. *Connecting new information to former knowledge*
    - Reminding the students to former concepts and principles of physics concept they have learned (e.g power, intensity, level intensity, Doppler effect)
    - Relating the basic concepts of mathematics knowledges (e.g fraction, logarithm, scientific notations) to the physics concepts and principles
2. *Selecting thinking strategies deliberately*
    - Sensing the physics problem by reading the text slowly to understand, remembering the symbols, identifying the magnitudes (vectors or scalar) and unit, interpreting the (word) problems
    - Selecting the basic concepts of mathematics knowledges (e.g converting the units)
3. *Planning and monitoring thinking strategy*
    - Sketching or drawing two dmensional-diagrams, writing the appropriate physics formulas or equations in the text (problems)
    - Interpreting the physics concepts and principle by using mathematical interpretations
    - Analyzing to make sure that the two dimensional-graphic (post) organizers (e.g.diagrams, graphs, or sketches) have constructed are helpful, make sense, intelligible, or must be revised
    - Doing or executing the computations by using the basic concepts of mathematics knowledges (fraction, logarithm, scientific notations) to find a right solution
    - Monitoring and making sure that all the computation, concepts and physic concept, and mathematical computations are correct

4. *Evaluating thinking processes, checking the results*
   - Rechecking the mathematical procedures and computations based on the physics problem they faced
   - Reinterpreting the physics concepts and principle by using mathematical interpretations and vice versa

The use of the model might be modified by any instructors compliance with their own occasions and constraints they faced in order to achieve the learning outcomes. The availability of the model I proposed might enrich the instructional interventions which may have been applied in the previous researches**.**

V. CONCLUSIONS

The emergence of initiatives to increase the quality of teaching-learning process in 21th century in terms of targeted content and skills, thinking processes (cognitive and metacognitive) in tackling solution of problem, and teaching pedagogy should be primarily used to guide the instructors for present day students. Therefore, a concrete definition of any instructional interventions for which students are expected to achieve the learning goals should be predetermined. Educators in the schools are impossible to make large-scale changes to current education settings due to be highly risky. Instructional intervention of learning in the classrooms need to be designed to adapt to environmental constraints.

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I declare that this paper is my original work and has not been published elsewhere, nor is it currently under consideration for publication elsewhere.

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