Learning transferable skills: the role of physics education in the era of disruptive innovation

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Abstract. In the era of disruptive innovation that filled with unpredictable problems, the study of physics should address the needs of the learners and prepare them with skills that can be applied in many areas of life. This paper reviews skills that tend to be widely used in various occupations or jobs, such as problem-solving, communication, leadership, and collaboration skills. These skills are often referred to as transferable skills or generic skills or core skills. The analysis was also undertaken to review the role of physics learning in developing transferable skills for graduates.

1. Introduction
Discoveries in technology can lead to changes in life. Among them may be the narrowness of a work field because it is no longer promising, or even disappears altogether because it is no longer needed. Thus, the adoption of new technologies and other innovations can impact future unpredictable situations. The change can cause anxiety or fear because it can disrupt the previously established situation. On the other hand, the change can also bring in newness or renewal and new opportunities, including new jobs.

That's the picture of the disruptive innovation era, where innovation can have disruptive effects that may be able to sense feelings of anxiety, perhaps even fears, but also provide a sign of renewal and growth [1]. Lately, this term has been the concern of many people in various fields, including in education [2,3].

This situation influences the practice of education as a process of preparing future generations. That is, if education does not undergo renewal, then the ability of the graduates it produces will become irrelevant. As a result, many graduates cannot easily adapt to the changes that occur in the disruptive innovation era. Education that should be able to produce innovators could be the graduates become a sacrifice of innovation.

Therefore, improvement of educational practices should be made urgent. In this case, it includes learning physics at school. The question is what skills need to be developed in education, including the study of physics, to anticipate changes in the disruptive innovation era?

Some literature discusses skills that can be used in various fields, including various fields of work. These skills include problem-solving, communication, teamwork, and leadership [4]. Such skills are called transferable skills, core skills, or generic skills, or soft skills, or Cross-Curricular Skills [4,5].

The next question is whether physics learning can be pursued to facilitate the development of transferable skills? How can it be sought? This paper aims to discuss the role of physics learning in developing transferable skills to face the era of disruptive innovation. The discussion begins by examining the definition of transferable skills, followed by a discussion of the role of physics learning.
2. Methods

2.1. Transferable skills in the school curriculum

History shows that innovation in technology has a tremendous impact on life change, for example, the invention of lights by Thomas Alfa Eddison and the recent discovery and application of the Internet in various fields. Innovation can also occur in institutions that are proven to be able to progress rapidly. It can happen because there are some creative individuals who are always innovating.

How great the role of innovation, education was directed to be able to develop the creativity of students. Similarly, education in Indonesia, school curriculum is directed to develop the creativity of learners, such as with the application of a scientific approach, which is observing, questioning, trying/experimenting, reasoning, and communicating [6], which is famous for “5M” (Indonesian: “mengamati, menanya, mencoba, menalar, mengkomunikasikan”).

There are two questions related to the scientific approach in our school curriculum. First, does 5M demonstrate the development of creativity like that of innovators? Secondly, does 5M include generic skills or transferable skills that are widely used in various areas of life/work? The question is tried to be discussed by citing the results of research by Dyer et al. [7], and relate it to the transferable characteristics of skill.

Dryer et al. has interviewed nearly one hundred of the world's best innovators, such as Amazon and Apple CEOs through a qualitative research approach. They found that the world's best innovators possessed the skills that set them apart from ordinary managers and executives. The skills of the world's innovators include: questioning, observing, networking, experimenting, and associating.

The results of Dryer et al. show that the world's best innovators "think and act differently". They like to ask questions, including questioning the status quo, likes to observe things that become more intensive than ordinary people, like hanging out with diverse people from diverse origins, like to experiment in their fields. Also, they are clever to associate or associate with ideas (which are cursorily unrelated) to generate innovative new ideas. These five skills, by Dryer et al.[7], refer to them as discovery skills, and those who have this discovery skill called the DNA innovator.

Dyer et al. continued his research by conducting a survey of over 500 managers and more than 5000 successful executives in the world, with success at the level below the first group interviewed. The survey results involving managers and executives from more than 75 countries show the same trend. They generally also have these five discovery skills.

Return to the 5M curriculum discussion of the 5M approach, i.e., observing, questioning, trying (including in collaboration), reasoning (including in associating), serving (including communicating and building networks). There seems to be a correlation between the results of Dyer et al. and 5M approach. This means that the school curriculum is anticipating the development of the times. If the curriculum can be implemented properly and well then it is expected to develop discovery skills. Further hope can be produced graduates who have DNA innovator.

Skills in the 5M approach as well as discovery skills, both of which are skills that can be used in various fields. Adaptive skills can be used in various fields of work, and the discipline is often referred to as transferable skills, generic skills, core skills, soft skills, cross-curricular skills [4,5]. So both discovery skills and scientific approach skills include transferable skills.

The encouraging information from Dyer et al. that the idea of innovation is not merely a function of the mind. In general, people assume that creativity is entirely a cognitive skill that occurs in a person's brain. The critical outlook from Dyer et al. shows that one's ability to generate innovative ideas is also a function of behavior.

This critical view implies that creativity can be developed through the educational process. Therefore, the application of a curriculum with a scientific approach, with 5M skills, is an effort to develop creativity. In other words, it can be stated that the development of transferable skills in schools is an anticipatory step to face an unpredictable and unpredictable disruptive innovation era. The next question is, can physics learning facilitate the development of transferable skills?
3. Results and Discussion

3.1. The role of physics learning

Science, including physics, is developed by humans to understand natural phenomena. Curiosity has encouraged scientists to undertake a scientific inquiry process or doing science [8], to find an answer or product that includes concepts, principles, theories, and laws. Through the scientific process, scientists try to understand nature. This process includes steps: exploring symptoms and formulating problems, creating temporary explanations (hypotheses), thinking of experimental designs to test hypotheses and predicting expected results as deductive consequences if experiments are realized, collecting data by observation or measurement, then comparing data with consequences deductive description of the hypothesis. If the data corresponds to the deductive consequence of the hypothesis gets support so that the new science is obtained that is tentative, and if not appropriate then the hypothesis is rejected or needs to be modified.

The thought process that associates or associates hypotheses, experimental designs, and predictions form a logical inference pattern if ... and ... then ..., i.e., if (the "true" hypothesis) and (designed controlled experiments) then (predicted would occur facts corresponding to deductive consequences of the hypothesis). The pattern of thinking, according to Lawson [9], actually describes the general human mindset that is not unlike the scientist's way of thinking, but because scientists are used or trained in using the pattern they can solve problems effectively. This association habits of thinking that also makes a person become an innovator.

The process of scientific inquiry is generally done by a collaborative scientist with his colleague or his assistant. To be able to cooperate well scientists should also have positive attitudes, such as honest, objective (without prejudice), skepticism (referring to evidence-supported information), and respecting or respecting people other. This kind of scientific attitude makes scientists have the competence to work together in teams that are very useful in the process of solving the problems it faces. Likewise, the habit of working together and networking also become one of the skills possessed by the innovator.

After a scientific research process finds out the result, the scientist is obliged to communicate the results through publication in a scientific journal carefully reviewed by colleagues. Publications with careful and in-depth review can be preceded by the presentation of research results in the form of posters or papers at a seminar. This scientific publication is very important because in the world of scientists apply the convention that the first inventor is not the first researcher but the person who publishes first in scientific journals.

After the results of research published or communicated then the results will be used by other researchers to conduct further research or apply it, so it can advance the science itself and contribute to the welfare of the community. Communicating is one of the generic (transferable skill) skills used in various fields.

The description besides showing that science, including physics, encompasses products, processes, attitudes, and ways of thinking, also shows that the usual scientific processes of work by scientists in the field of physics involve problem-solving competencies, teamwork, and communication. When the study of physics proceeds as advised by experts [10], that is learning that gives students the opportunity to "discover" rather than simply "receive", the learning involves many of these three competencies, as learning to discover means learning physics such as physics discovered by scientists (learning physics as physics is done). Thus, physics learning makes it possible to serve as a generic skills development vehicle.

Learning opportunities for self-discovery of concepts can be developed, among others, in the form of learning strategies with discovery or inquiry approaches as suggested by many experts [8, 9, 11-14]. The inquiry approach is chosen with consideration of the results of the research showing that the approach can facilitate students to solve problems through scientific inquiry so that students can find their answers. The results also show that the application of inquiry approaches has increased interest [15], developing scientific capabilities, such as explaining, predicting, designing experiments,
collecting and analyzing data, drawing conclusions, communicating [16-17], and resulting in improved retention of learning outcomes [18].

Inquiry learning can facilitate students to solve problems to find their solutions. The solution is a product of new knowledge for students, which can be concepts, principles, theories, or natural laws. The product, which is the conclusion of a scientific process, then needs to be communicated, both in written and written, so that students can develop communication competence. These communicative competence indicators include presenting and reading the results of a scientific process in the form of numbers, equations, tables, graphs, symbols, and narratives.

To test the hypothesis, scientists designed the experiment and carried it out. In experimental execution, there are several activities to be performed simultaneously, such as controlling and varying variables, performing observations/measurements, and recording data. Therefore, experimental activities are usually carried out in groups. In this way, students have the opportunity to develop learning competencies to work together in groups or teams.

At the end of the experimental activity, students are required to report the results in writing in the form of reports or lacquers in the form of group presentations in front of the class. The process of preparing and presenting this report can serve as a vehicle for developing communication competence. The description illustrates clearly that physics learning with inquiry approaches can facilitate the development of discovery skills as well as transferable skills. The next step that needs to be discussed is how the more concrete learning model can be applied in the classroom. What is interesting in this era of disruptive innovation where the internet has become a vast communication medium, physics learning can also take advantage of this facility. Physics learning can also be organized through social media, such as Facebook (see case of water seepage or leaking pipes covered in Facebook Wi Yan To https://www.facebook.com/wiyan.to.77).

4. Conclusion

The 2013 curriculum with a scientific approach has introduced the skills of observing, questioning, trying/experimenting, reasoning, and communicating. The skills of questioning, observing, networking, trying, and associating by Dyer are called the discovering skills common to innovators. Skills in such scientific approaches and discovery skills include transferable skills that are widely used in various fields of work. Through scientific inquiry, physics learning can facilitate learners to develop transferable skills. In this disruptive technology era, physics inquiry learning can be held interactively by utilizing IT technology such as the internet, even can utilize social media like Facebook.

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