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EkSTEMiT Learning Module and Inculcation of Inventive Thinking

***Norhaslinda Abdul Samad, Kamisah Osman**
Faculty of Education, National University of Malaysia, Bangi, Selangor
**E-mail: lindafird@gmail.com*

Abstract

The young generation of today must be prepared with the knowledge and skills necessary to be able to compete globally thus boosting economic growth and prosperity. Therefore, students should not only be equipped with knowledge but they are in need of the "21st century skills", which is the top priority and one of the main education agenda goals today. As one of the domains in the 21st century skills, inventive thinking includes elements of flexibility, self-regulation, curiosity, creativity, risk taking, higher order thinking and reasoning. In order to inculcate inventive thinking for students, the EkSTEMiT Learning Module was developed for the topic Electrochemistry; one of the most difficult topics to learn among students. EkSTEMiT Learning Module was developed based on the STEM (Science, Technology, Engineering and Mathematics) integrated model. Thus, this paper will discuss the conceptual framework underlying the development of EkSTEMiT Learning Module with descriptions of learning activities designed for Electrochemistry.

Keywords Inventive Thinking; STEM Approach; Electrochemistry learning

Introduction

As a result of the uncertainties in the competitive global economy, Malaysia is required to exploit science and technology (S&T) as a determinant of the country's economic sustainability. S&T is seen to transform the country into a knowledge-based economy (K-economy) to drive competitiveness in the 21st century. Accordingly, the manpower needed in the field of S&T will require competence and innovative as the main priority. This noble goal can be fueled with acculturation integration of STEM (Science, Technology, Engineering and Mathematics) and 21st century skills that can lift Malaysia as contributors and not just consumers of knowledge and technology. Integrated STEM provides opportunities for students to develop and explore technology through educational means in the context of real life (Johnson, Peters-Burton & Moore, 2016). Inventive thinking is one domain in the 21st century skills needed to establish an individual who not only knowledgeable but also to master a variety of skills-based technology (Sanariah, Mastura & Kamisah, 2012).

Recognising this, various strategies and initiatives have been taken to realize the nation's goals. However, there are constraints and challenges to be overcome. Everybody knows that chemistry is the science that consists of many aspects, including the abstract and complex (Talanquer, 2013; King, 2012). This has affected the electrochemistry topic, which has been identified among the most difficult topics as determined by students (Lee & Kamisah, 2010; Karamustafaoğlu & Mamlok-Naaman, 2015; Lay & Kamisah, 2015). In addition, the level of inventive thinking in students appears less impressive. According to Mohammad Mohsin and Nasruddin (2008), the education system, the behavior of the teacher in the classroom and peer pressure are obstacles and challenges in fostering creativity. These obstacles, coupled with teacher-centered learning have eroded self-direction skills among students (Smit, de Brabander & Martens, 2014). Meanwhile, higher-order thinking among students in Malaysia is poor and thus very alarming, especially in answering science questions and solving science problems (Kamaleswaran, Rohaida & Rose Amnah, 2013). In the context of integrated STEM, engineering is considered difficult and hard to be learned by the community because it consists of various branches of science and is often misunderstood by the public (Poll, 2004).

Overall, students' mastery in chemistry and 21st century skills can affect the manpower needs in the future in the fields of Science and Technology (S&T). This in turn may have an impact on the national economy in pursuit of developed nation status. Therefore, sustainable measures should be taken to improve student achievement, especially for the topic of electrochemistry, while at the same time foster inventive thinking. This paper will discuss the conceptual framework underlying the development of the EkSTEMiT Learning Module through STEM teaching and learning strategies that foster innovative and inventive thinking in students.

Inventive thinking

Inventive thinking refers to the cognitive skills that are critical to complete a specific task with simple and easy solutions using the latest technology (Sanariah, Mastura & Kamisah, 2012). According to enGauge (NCREL, 2003), inventive thinking is a domain that is essential for success and thrives in the 21st century. Inventive thinking consists of six sub domains, namely flexibility, self-regulation, curiosity, creativity, risk taking and higher order thinking and reasoning.

Flexibility or adaptability in complexity management refers to the ability of students to change the way of thinking, attitudes and actions in addressing the task in a limited time and resources while learning. Students will be able to identify and understand the changes and positive thinking to modify thoughts, attitudes and behaviors to manage the new environment. The second sub-domain is self-regulation, which allows students to set goals, make a plan to achieve the learning goals, manage time and assess the quality of learning independently. Next is the third sub domain which is curiosity. It refers to students' curiosity in learning something and inquiries during learning; it is an essential component of life-long learning. The fourth sub domain is creativity, which allows students to generate new ideas and genuine products, to make judgments on the ideas put forward that are powerful, generative, imaginative, and sensitive to the environment and then assess themselves freely. The fifth sub domain of risk refers to the willingness of students to make mistakes and willingness to accept challenging assignments, share information and receive feedback from peers. The last sub domain is higher-order thinking and reasoning. Higher order thinking and reasoning refers to cognitive processes like analyzing, comparing, evaluating and synthesizing learning problems and current information. Students are able to compare the analysis, making inferences and interpretations, evaluate and resolve the problem of the assignment and apply to everyday life.

Inventive thinking is an aspect of 21^{st} century skills that is important to produce innovative thinkers who can contribute to national prosperity. Inventive thinking prepares students with the creativity, innovation and exploration to think outside the box and solve real problems.

The underlying theory of EkSTEMiT Learning Module

There are two theories that trigger the learning and coaching of EkSTEMiT Learning Module: Constructivism Theory and Constructionism Theory.

Constructivism Theory

Constructivism learning theory focus on students constructing their own knowledge. The theoretical framework of constructivism was influenced and developed by many educational leaders, especially Jean Piaget, John Dewey and Maria Montessori. According to

Piaget (1977), when students encounter new information, the process of assimilation and adaptation will occur. Students will compare the new information with existing knowledge gained there in their minds. If the available information is not compatible with the new information, a student will coordinate his mind in connection with the new information. However, Dewey (1966) argues that knowledge is gained from experiences in life. Students experience learning through self-direction in which they apply the concepts learned with meaningful activities. This creates an environment of real life learning in the classroom. In addition, the study proposed by Montessori (1997) encourages creative problem solving where students independently solve problems and teachers serve as facilitators.

Generally, the theory of constructivism emphasizes the constructive knowledge of the environment in which learning occurs actively and collaboratively. In addition, activities in the classroom are student-centered and authentic in nature, either individually or collectively. Meanwhile, teachers act as facilitators, giving encouragement and focusing on students' learning.

Constructionism Theory

Constructionism theory is a branch of constructivism theory. Constructionism theory states that learning is not a reconstruction of knowledge and knowledge transfer. Effective learning is when students are involved with the production of artifacts or meaningful products (Papert, 1986). Constructionism theory focused on learning through or by making shows how an idea is formed and transformed when presented through a different medium and subsequently realized contextually (Ackermann, 2001). Papert (1991) said, "Constructionism—the N word as opposed to the V word—shares constructivism's view of learning as building knowledge structures through progressive internalization of actions. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe."

Developing the EkSTEMiT Learning Module

The EkSTEMiT Learning Module highlights Electrochemistry topics through integrated STEM in fostering inventive thinking skills among students in form four (age 16-17). Integrated STEM refers to the teaching and learning of content knowledge and practice of Science and Mathematics, or both through the integration of engineering design (E in STEM) and practices to produce a technology (Johnson, Peters-Burton & Moore, 2016). This module was developed based on ADDIE; Instructional Design Model, which is an acronym for phase Analysis, Design, Development, Implementation and Evaluation (Molenda, 2015). The ADDIE model provides an approach to the systematic development of modules and can be adapted to all stages of the design of teaching and learning (Campbell, 2014). In addition, the teaching model applies Needham's Five Phases of teaching and learning in the classroom. The five phases of instruction in this model are orientation, eliciting of ideas, restructuring of ideas, application of ideas and reflection, which review the ideas discussed (Needham 1987). The orientation phase aims to gain attention and interest of students and motivate students to set learning goals. The phase of eliciting ideas enables students and teachers to identify existing misconceptions and prior knowledge whereas the phase of restructuring ideas serves to create awareness of the scientific outlook for modifying, connecting and converting to a more scientific view. Next, the phase of application of ideas is used to identify newly renovated or constructed ideas from the restructuring phase and apply the idea of the new situation and reflection phase to assess and evaluate student understanding of the previous ideas that have changed. EkSTEMiT Learning Module's idea is implemented in the application phase. During this phase, the acquired knowledge is applied to the new situation in a problem solving context. For example, students design and construct a computer simulation to show the process of electrolysis. This can help students to understand the electrolysis process that has been perceived as difficult and abstract.

Development of design thinking is emphasized in this module corresponding to the theory of constructivism and constructionism. Most of the learning process design implemented in schools is challenging where measures are gradual and indirect (Martinez & Stager, 2013). In this module, students are provided with a step by step guide, which is cyclical, with the tools and information necessary to enable them to manage ideas and to be able to design a product or artifact that is produced effectively. The Creative Design Spiral Model is applied to help students generate new ideas and invent designs (Fig.1). The Creative Design Spiral Model is a cycle in which students first imagine what to do, then design a project of their ideas, experiment or test their creations, share ideas and creations and ultimately make a review of the experience. This repetitive process will build their own ideas, which in turn can generate new ideas based on experience (Rusk, Resnick & Cooke, 2009). According to Chunn (2009), the design cycle enables students to develop more complex and more understandable engineering concepts. At the same time, inventive thinking is applied to the phases of the Creative Design Spiral so that students can develop and assess their own skills acquired from learning.

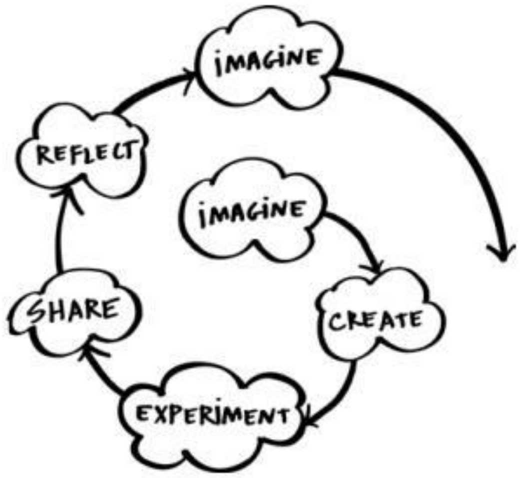

Figure 1. *Creative Design Spiral*

Implementation of EkSTEMiT Learning Module

The following are descriptions and examples of the teaching and learning process implemented from EkSTEMiT Learning Module for the sub topic "electrolysis of molten compounds".

Orientation phase

- Teachers introduce electrolysis to demonstrate the connection button buzzer that buzzes when a circuit is completed.
- Students are asked to give an opinion on how the buzzer can produce sound.

Eliciting of idea phase

- Students are given a type of material and they are then required to classify these materials as electrolytes or non-electrolytes.
- Students explain why each material is classified into the electrolyte or non-electrolyte group.

Restructuring of idea phase

- Students conduct experiments to study the electrolysis of molten Lead (II) Bromide, $PbBr_2$.
- Students record observations, decisions and discussions as required in the practical text book.
- Teachers monitor the practical method, making observations of Science process skills and students' manipulative skills, providing assistance to students if necessary and monitoring safety during the experiment.
- Students are taught how to make conclusions based on the findings of an experiment for ion concentration factor.
- Students are also required to find the meaning of electrolysis, conductors, electrolyte, non-electrolyte, anode and cathode, anions and cations.

Application of idea phase

- Students carry out activities that are within the EkSTEMiT Learning Module where they design a computer simulation that shows the state of the ion in the compounds of molten lead (II) bromide, $PbBr_2$, the movement of ions to the electrode and the ion discharge during electrolysis of molten $PbBr_2$ using the MS Power Point software.
- Measures to design a computer simulation are included in the EkSTEMiT Learning Module.

Steps	Explanation	Inventive Thinking
Imagine	Planning Design 1. Students are required to use MS Power Point software to design computer simulations for the electrolysis of molten compound lead (II) bromide, $PbBr_2$. 2. Students are required to design and sketch a plan.	Self-Regulation, Risk
Create	The steps of designing a computer simulation of the process of electrolysis of molten compound of lead (II) bromide, $PbBr_2$ steps can be referred as below: 1. Anions (negative ions) will be attracted and move toward the anode. Anions release electrons at the anode surface and form the atom or molecule. Anions are discharged at the anode. 2. The electrons flow from the anode to the cathode through the external circuit wires. 3. Cations (positive ions) will be attracted and move towards the cathode. Cations receive electrons at the cathode surface and form an atom or molecule. Cations are discharged at the cathode. 4. The flow of electrons through the external circuit and the chemical changes that occur in the anode and cathode are shown.	Self-Regulation, Creativity

Experiment	Simulation experiment 1. Students are required to test the computer simulation for the electrolysis of molten compound lead (II) bromide, $PbBr_2$ (which has been designed). 2. Pupils test the simulation repeatedly to see the effectiveness of their inventions. 3. Improvisation can be done by changing the effect option, animation painter, animation and trigger pane.	Curiosity, adaptability and complexity management
Share	Sharing and presentation 1. The results of the simulation design are shown to the teachers and peers from the other groups. 2. Comments and proposals received from other groups and teachers will be considered. 3. Students improvise from the sharing session with friends and teachers.	Higher-order thinking, adaptability and management complexity
Reflect	Reflection and evaluation 1. Students are required to assess the experience gained from this activity. 2. Students check the extent of the changes to their understanding, abilities and competencies for themselves.	Higher-order thinking, Self-Regulation
Imagination	The beginning of a new cycle in which the process of repetition underlies the process of creativity. Students go through the imagination-create-experiment-share-reflect process that will generate new ideas and launch a new creative cycle.	

Review Phase

- Students record their reflection in the assigned worksheet where they are given four chemical compounds and the target is to write half equations and the products formed at the cathode and anode.
- Students check the extent of the changes to their own understanding, abilities and competencies.

Conclusion

The EkSTEMiT Learning Module was developed to improve students' performance in Electrochemistry topics and foster inventive thinking in teaching and learning in formal and systematic ways. EkSTEMiT Learning Module integrates the strategies of teaching and learning and interdisciplinary approach through design activities. The module allows students to build knowledge through experience and product design artifacts for collaboration. In addition, this module emphasizes the integration of information and communication technology (ICT), inquiry-based learning and project-based learning (PBP). This approach is expected to prepare students with the knowledge and skills required to meet the needs of skilled manpower in the field of S&T that will drive the country's economic prosperity.

Norhaslinda Abdul Samad *is a master student (Science Education Programme) at the Faculty of Education, National University of Malaysia, Malaysia. After receiving his B.Sc.Ed. from University of Malaya in 2006, she taught chemistry at Dato' Abdul Samad Secondary School, Negeri Sembilan. Currently, she is a Chemistry instructor attached at the National Gifted Centre, National University of Malaysia, Malaysia. Her research interests include pedagogical approaches in STEM education and 21st century skills.*

Dr. Kamisah Osman*, is a Professor from UKM in Bangi in the Department of Teaching and Learning Innovation, Faculty of Education. Dr. Kamisah Osman earned her master's and Ph.D. degrees at the University of Manchester, United Kingdom. She was the executive editor of* Asian Journal of Learning and Teaching in Higher Education *(2013–2014), an active editorial board member of the* Eurasian Journal of Science and Mathematics Education, International Journal of Education in Mathematics, Science and Technology, Science Education Review, Malaysian Journal of Education, Malaysian Action Research Journal, AKADEMIKA Journal of Southeast Asia Social Sciences and Humanities *and more recently* Educational Process: International Journal. *Her expertise is STEM education, specializing in the assessment of problem-solving and higher order thinking as well as innovative pedagogical approaches in STEM learning.*

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