STEM-21CS Module: Fostering 21st Century Skills through Integrated STEM

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Introduction

- The shift in this current world economy from a manufacturing-based to knowledge-based economy, scientific innovation and advances in ICT have changed the job market in this modernised era.

- Malaysia is in need of knowledgeable human capital in order to generate innovative thinking to remain competitive globally.

Introduction

- The generation of innovation in science and technology (S&T) has been an important key towards the country's effort in becoming a fully developed nation by the 21st century.

- Malaysia should first produce human capital that is both knowledgeable in the field of STEM and equipped with 21st century skills.

Integrated STEM

- An integrated STEM approach is necessary for addressing global and local challenges, as well as for success in careers of today and those anticipated in the future (Moore *et al.*, 2016).

Integrated STEM should emphasize **solving real-world problems.**

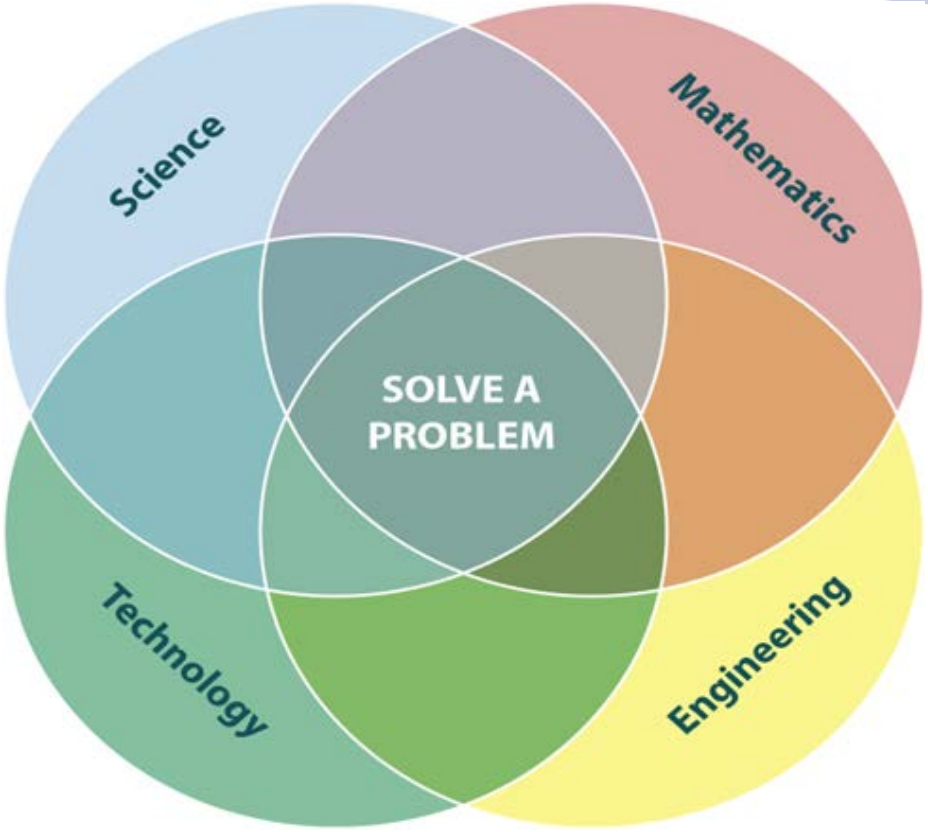
- This may include exploring approaches to tackling world grand challenges of our era, such as health, energy efficiency, natural resources, environmental quality and hazard mitigation (Bybee, 2010).

Integrated STEM

* The integration of STEM provides opportunities for students to develop and explore technology through meaningful learning process in real-life context (Johnson, Peter-Burton & Moore, 2016).

* Students fully equipped with STEM knowledge are able to identify, apply and integrate its concepts in order to understand complex problems and generate innovative solutions to solve those problems (Chew *et al.*, 2013).

Integrated STEM



21st Century Skills

* 21st century skills are important in preparing students to remain relevant in life and work of the 21st century which undoubtedly are very complex and competitive. (Partnership for 21st Century Skills, 2009; Osman, Abdul Hamid & Hassan, 2009).

* Realising the prerequisites of 21st century skills, Malaysia has participated in international assessments such as Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA) to assess students' achievements and skills.

21st Century Skills

* However, the results achieved by students in TIMSS and PISA were not encouraging (IEA, 2012; OECD, 2013).

* This is due to the lack of efficiency in T&L methods and our current educational system which does not emphasize on higher order thinking skills (HOTS) (Nik Pa, 2014).

* Moreover, the results also show that the adoption of 21st century skills are lacking in the T&L process. It was identified that students failed to apply their knowledge in using critical thinking skills to solve real-life problems (Kay, 2009; Ministry of Education Malaysia, 2013).

21st Century Skills

* The combination of 21st century skills and content knowledge are equally important and this combination should be applied to students even during their lower secondary level (Kay 2009; Rotherham & Willingham 2009).

* Students will be more prepared to enter a higher secondary level learning with solid curriculum if these 21st century skills are exposed to them in advance.

21st Century Skills

* Halim (2013) concluded that STEM education is the perfect medium for the implementation of 21st century skills.

* This situation indirectly implies that the current educational system should not neglect STEM education which is capable of fostering 21st century skills and create a society that is able to compete globally.

Interdisciplinary Approach

* STEM integration functions as a channel in fostering 21st century skills with subject content.

* The application of STEM interdisciplinary approach and STEM T&L strategies such as project-based learning, problem-based learning and inquiry-based learning can be applied simultaneously in the integration of STEM.

* This is to ensure that students will be able to develop meaningful knowledge and learning by themselves as the STEM T&L approaches and strategies connect them with the real world and daily life problems.

Interdisciplinary Approach

* In accordance with the trend of a 21st century education, separation of subjects is less relevant in allowing students to master various knowledge and solving non-routine problems.

* STEM integration can prevent STEM subjects to be taught separately and discretely as practiced in school nowadays.

Interdisciplinary Approach

* Interdisciplinary approach can be defined as a mode in using methods or knowledge of more than one discipline to analyse an issue, problem, or topic (Jacobs, 1989).

* Customarily, interdisciplinary education is problem-centred and correlates the knowledge of several disciplines in order to solve complex real-life problems (Nikitina, 2006).

* All four separate disciplines in STEM are combined into one through an interdisciplinary approach.

Interdisciplinary Approach

* Cantu (2011) found that this approach can diminish the "silo" teaching effect separately in science, technology, engineering and mathematics.

* Thus, it allows students' learning experience to be more consistent and relevant compared to the separate delivery of concept in curriculum that focuses on a single subject (Nordin & Othman, 2008).

Interdisciplinary Approach

* Apart from that, information obtained from various fields can be combined in an effective way to increase students' understanding, knowledge application, involvement, interest, motivation, problem-solving skills, cooperative learning and 21st century skills (Barlex, 2009; Klein, 2006; Price *et al.*, 2011; Roberts & Cantu, 2012).

STEM-21CS Module Development

* Since traditional didactic T&L methods have been firmly rooted in the Malaysian classroom, it will be challenge to shift traditional T&L methods into 21st century T&L methods.

* As a starting point, we may want to try to incorporate traditional subject-content with 21st century skills (Fogarty & Pete, 2010).

* Therefore, the researcher propose to develop a STEM-21CS Module, which integrates T&L on the topic of Dynamic (Science Form Two- Lower secondary-14 years old) with technology, engineering and mathematics skills.

STEM-21CS Module Development

* Students are also given exposure with activities in the STEM-21CS Module that require them to become engineers to solve real-world problems.

* The objective is to increase students' interest on the jobs listed in STEM field in the future.

Underlying Theories in STEM-21CS Module

Learner actively constructs new knowledge pursuant to his/her existing knowledge

ConstructiVism

Learners should be given the opportunity to **explore** the new knowledge (Bruner, 1966).

Construction of new knowledge can be improved through **social interaction** (Vygotsky, 1978).

Underlying Theories in STEM-21CS Module

ConstructioNism

Construction of new knowledge happen felicitously in a context where students are consciously involved in the **production of external and sharable artefacts** (Papert, 1991).

Emphasize the **role of design** (making, building or programming) (Kafai & Resnick, 1996) and **external objects** (Egenfeldt-Nielsen, 2006)

STEM-21CS Module Development

Instructional Model

BSCS 5E Instructional Model (Bybee, 2009)

- Engagement
- Exploration
- Explanation
- Elaboration
- Evaluation

STEM-21CS Module Development

Creative Design Spiral

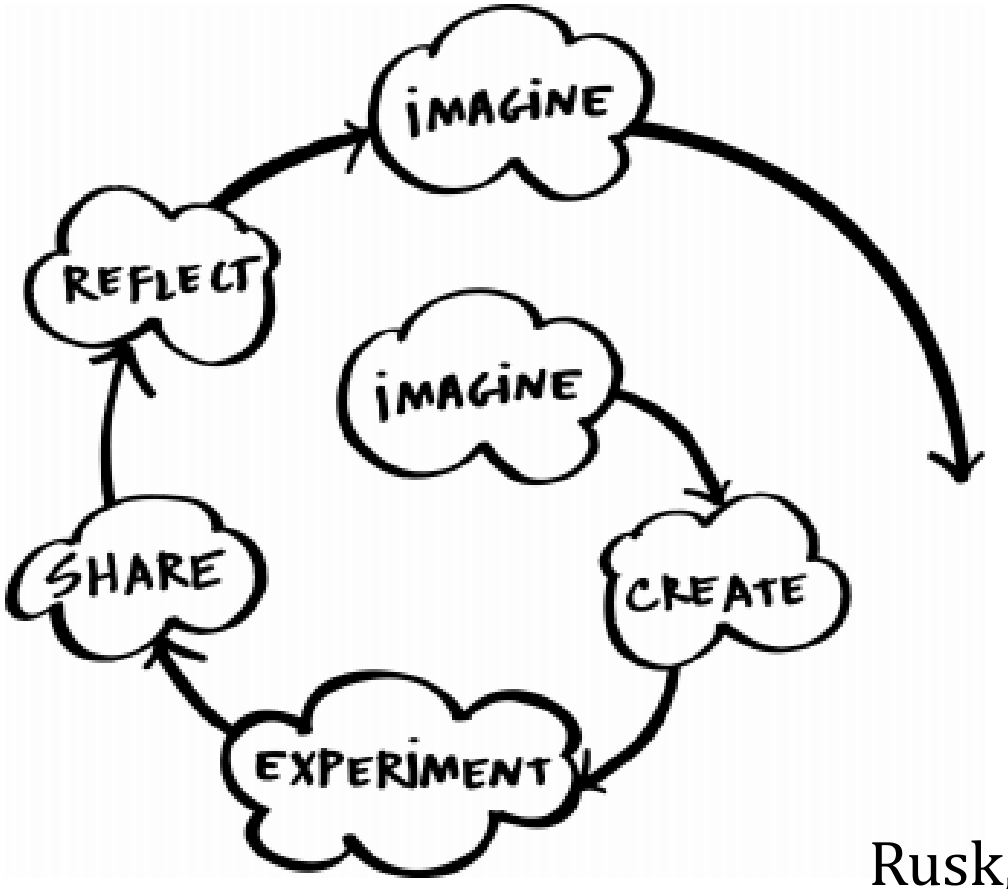
- In order to help students develop ideas, an engineering design model was applied. The engineering design model, which is Creative Design Spiral was introduced by Rusk, Resnick and Cooke (2009) to help student complete their design project.

Creative Design Spiral

* In this process, students will discuss about the watermill design (imagine), create watermill (create), test the produced watermill (experiment), share ideas to gain input from other groups (share), make a reflection of the strength and weaknesses of produced watermill (reflect) and improve the quality of watermill based on inputs from other groups, reflection, and tests that were conducted (imagine again).

* When students are guided to experience the new process in Creative Design Spiral repeatedly, new ideas will continuously form.

Creative Design Spiral



Rusk, Resnick & Cooke (2009)

Example of Activity in the STEM-21CS Module

Activity Description

In this activity, you are working for H_2O Solutions, an engineering design firm that works mostly with water wheels and water energy! Your city wants to use hydropower instead of fossil fuels to make energy because they are worried about air pollution. The city has hired you to design an efficient watermill. The firm (our class) has been split into several engineering teams (student groups). Each engineering team will design and test a slightly different design so that the firm can present the most efficient design to the city. You will calculate power and work by measuring force, distance and time for your team-built water wheel.

Engage	• Teacher shows video of water wheel that can produce electricity. Video URL: https://www.youtube.com/watch?v=bNltaZ4RE2o • Teacher asks several questions to students about the video What is the water wheel? How does it work? Why water wheel is needed? How is it used to do work? What makes it move? • Students discuss in groups and compare their ideas with the peers.

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Explore

Scenario: Energy Security Issues

Malaysia still relies heavily on gas and coal for power generation where for Financial Year 2015, gas made up 48.13% of the total energy generated by Energy Authorities of Malaysia (TNB), followed by coal (40.14%), hydro (11.64%) and distillates (0.09%). A strategic transformation is required urgently to meet the future energy supply. Dependence solely on fossil fuels possess both economic and security risks.

(Source: https://www.tnb.com.my/assets/annual_report/2015_annualreport.pdf)

Explore

*Remark: Students are encouraged to collect relevant information from the Internet and other sources

Your team challenge is to design an efficient water wheel that can generate power. You need to use your knowledge in science, technology and skills in mathematics to consider the features of a good water wheel.

The following guidelines may be useful in helping your group to solve the problem

- Imagine what you want to do (how to design an efficient water wheel).
- Create a project based on your ideas.
- Do experiment with alternatives.

Explain	• Defend and share your ideas and creations with others (your group will prepare a portfolio for your idea). • Show the real product during the class presentation.

Elaborate	• Reflect on your experiences. • Imagine new ideas and new projects. • You are encouraged to upload your group's design onto YouTube and other social media and be prepared to receive comments from other users.
Evaluate	• Performance based assessment. • A rubric form is used to evaluate the effectiveness of the design in the aspect of power produced by the water wheel, cost, user-friendliness, creativity, environmentally-friendly, usability, and relevance etc. • Peer-assessment, self-assessment, and teacher assessment.

Inculcation of 21st Century Skills through the STEM-21CS Module

* The development of STEM-21CS Module endorses the 21st century skills framework provided by Osman & Neelavany (2010).

* Researcher has chosen this framework as it takes account of the spiritual and noble values as an added value to the 21st century skills framework proposed by NCREL and Metiri Group (2003).

* This is to ensure that it is aligned with the National Educational Philosophy in Malaysia which conforms to the Physical, Emotional, Spiritual, and Intellectual concept. 21st century skills framework provided by NCREL and Metiri Group (2003) is composed of four main domains which are digital era literacy, inventive thinking, effective communication, and high productivity.

enGauge 21st Century Skills

NCREL & Metiri Group (2003)

21st Century Skills

Osman & Neelavany (2010)
Digital-Age Literacies
Inventive Thinking
Effective Communication
High Productivity
Spiritual and Noble Values

Digital age literacy	• Basic literacy, scientific literacy, economic literacy and technology literacy • Visual literacy and information literacy • Multicultural literacy and global awareness
Inventive thinking	• Adaptability and managing complexity, and self-direction • Curiosity, creativity and risk taking • Higher-order thinking and sound reasoning
Effective communication	• Teaming, collaboration and interpersonal skills • Personal, social and civic responsibility • Interactive communication
High productivity	• Prioritizing, planning, and managing for results • Effective use of real-world tools • Ability to produce relevant, high-quality products
Spiritual and noble values	• Thankful to God • Having an interest and curiosity toward the environment • Being honest and accurate in recording and validating data • Being diligent and persevering

Domain	Example of activities for the topic of dynamic
Digital age literacy	• Students find relevant information from reliable websites. • Students use advanced technological devices like digital cameras to record the evidence in project.
Inventive thinking	• Students play the role of engineers who need to design an efficient water wheel that can generate power. • Students need to use their knowledge in science, technology and skills in mathematics to consider the features of a good water wheel.
Effective communication	• Presentation in the classroom. • Students use a variety of platforms to share the design of their water wheel such as via YouTube, Facebook, email, blogs etc.
High productivity	• Students write portfolio for the use of recyclable materials to design an efficient water wheel that is useable in the real-life context.
Spiritual and noble values	• Students carry out teamwork and instil values of collaboration among team members. • Students exhibit a sense of responsibility for their own investigation by collecting data honestly.

Conclusion

* The challenging life in the 21st century demands for Malaysians to be knowledgeable and skilled in the field of STEM.
* STEM education which emphasizes the interdisciplinary approach is essential to cope with global and local challenges.
* The engineering practices applied and integrated with science and mathematics is needed in designing a technology that is capable of solving problems in real-world.
* With the connexion of all four disciplines, expectantly students can be equipped with the 21st century skills which are absolutely necessary in this new era.

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