Integrated Robotics STEM Curriculum Towards Industry 4.0

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Abstract—**In consideration of future employment in STEM domains, university graduates should be prepared to meet the demands of industry 4.0 – resulting from a fourth industrial revolution. Based on the technological concept of cyber-physical systems and the internet of things, it facilitates – among others - the vision of the smart factory. As a result, robotics education is faced with a large potential field of research, which ranges from the technical development and didactical students' acceptance or the proof of concept of the terms of learning efficiency. This paper presents a conceptual framework to investigated which kinds of learning outcomes prefer in a robotics education in secondary school STEM curriculum. Building upon the results content analysis, a collaborative STEM curriculum using robotics as a platform was created within the collaborative competition environment. It is expected that the students exposed to the robotics curriculum in secondary school would continue to pursue the engineering course in university. Therefore, this is an important contribution towards a globalized and digitalized working world in terms of industry 4.0.**

Keywords—**industry 4.0; robotics; education; curriculum.**

I. INTRODUCTION

IN today's world, it seems all students need to be equipped with STEM knowledge and the creative problem-solving skills necessary to be innovative and creative thinkers. The vision of "industry 4.0" is characterized by highly individualized and at the same time cross-linked production processes [1].The digitalization of education system also means that learning becomes more collaborative. Recently, robotics education has built a track record in STEM education by providing resources that are engaging, familiar, and relevant to young learners so that teachers and facilitators can deliver high-quality, hands-on curriculum that encourages creativity and problem solving while strengthening the abilities and skills needed for students to be successful in the core classroom [2], [3].

The curricula at all levels in Malaysia are developed to address the needs of all students, regardless of race, socioeconomic and gender. The current curriculum design adopted by the Curriculum Development Division of the MOE, is a standards-based thinking oriented curriculum [4]. Students engage in learning experiences by thinking about and thinking with what they are learning. It is hoped that the findings of this study would spearhead the formal training of robotic education in the Malaysia education curriculum using Robotics curriculum to enhance integrative STEM education. By integrating educational robotics into the latest standards-based STEM curriculum, teaching tools, and appropriate hardware and software that can help turn to ordinary learning into dynamic, performance-boosting learning environments [3], [5], [6].

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The spotlight is now focus on how the learners learn and the how to design an effective learning environment. Parallel to this shift in pedagogy, the integrated STEM curriculum has emphasized the need for reform to modernise Malaysia STEM education.

II. LITERATURE REVIEW

Since 21st century, Malaysia economy moves from a manufacturing-based economy to an information and service-based economy, thus the demand for a workforce well educated in science, technology, engineering, and math (STEM) is growing. Unfortunately, the number of students who choose STEM fields continues to decline [7]. Research on integrative instruction that focuses on Science, Technology, Engineering, and Mathematics (STEM) is important, because the jobs of tomorrow are rooted in STEM fields. Although the written curriculum developed by the Ministry of Education (MOE) specifically states that STEM education includes three main components which are knowledge, scientific skills and scientific attitudes, however there is a gap between the aspired curriculum, implemented curriculum and examined curriculum [8]. The implemented curriculum does not reflect these three focus very well and the examined curriculum did not reflect this balance in integrative STEM education either. Educators are always searching the best pedagogy to improve students' achievement, skills, and attitude toward learning STEM subjects, However, the current traditional curriculum is more teacher-cantered than learner rather than the learner-cantered.

In recent years, there has been a change in basic assumptions taking place, moving the emphasis from teaching to learning and a more student-centred curriculum especially in STEM subjects [9]. This change has impacted on the curriculum design process with a greater emphasis on the learning activities through project-based in terms of knowledge, skills and competencies within courses and modules [10], [11].

The objective of this paper is to propose a new integrated STEM curriculum using robotics as an agent to deliver the content and learning activities.

III. METHODOLOGY

A conceptual framework for Integrated Robotic STEM curriculum is designed in this study as a guideline for curriculum development as in Fig. 1. The new framework focuses on using educational robotics in STEM learning as an outcome while capitalizing on the acts of workplace readiness as versioned in Industry 4.0.

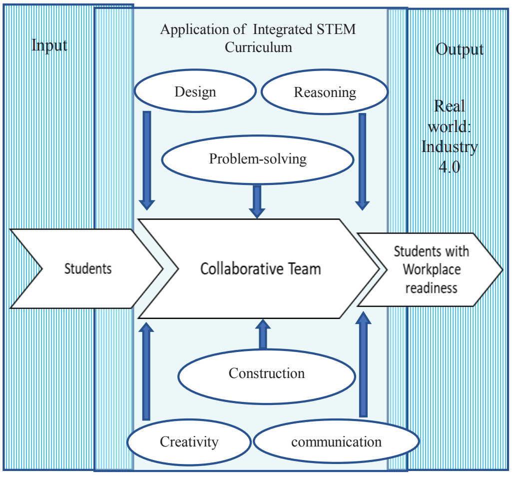

Fig. 1. Conceptual framework of integrated STEM curriculum [12]

The curriculum is designed based on the following principles:

1. Provide learning objectives and examples of learning modules for various robotics concepts
2. Present a comprehensive set of competencies based on these concepts for effective robotics understanding
3. Promote a set of competencies for using robotics concepts to teach or reinforce cocurricular concepts (programming, engineering design, math, science, etc.)
4. Offer flexibility across academic level or robotics experience.

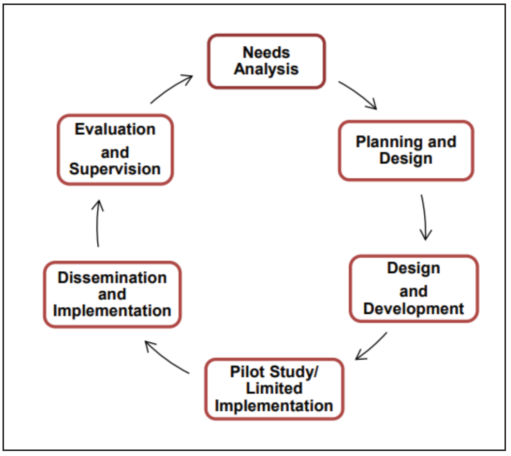

Fig. 2. Curriculum development cycle model [13]

IV. ANALYSIS

The new STEM frameworks integrates the existing framework from Science 5E Instructional Model [14], Technological literacy framework [15], PISA Mathematical Literacy [16], Engineering Design Challenge [17], and Robotics Experiential Learning [18], which allows students to scope, design, create, evaluate, review and improve their solutions:

TABLE I. Existing Stem Frameworks

Existing Framework	Components
Science 5E' Instructional Model	Explore, explain, elaborate, evaluate
Technological Literacy Framework	Communication, problem solving, creativity, and thinking skills in a meaningful context
PISA Mathematical Literacy	Formulating situations mathematically, Employing mathematical concepts, facts, procedures and reasoning, Interpreting, applying and evaluating mathematical outcomes
Engineering Design Challenge	Five comprehensive core engineering design processes: Problem scoping, Idea Generation, Design and construction, Design evaluation, Redesign.
Robotics Experiential Learning	Experience, Share, Process, Generalise, Apply.

V. RESULTS

TABLE II. New Robotics STEM Curriculum Framework

	SCIENCE	TECHNOLOGY	ENGINEERING	MATHEMATICS	ROBOTICS
Skills and processes	**5Es instructional model**	**Design and Technologies**	**Engineering design process**	**PISA mathematical literacy framework**	**Experiential learning model**
Investigating and scoping	**Engage** • Create interest and stimulate curiosity • Set learning within a meaningful context • Raise questions for inquiry • Reveal students' ideas and beliefs, compare students' ideas	**Investigating and defining** • Critique needs or opportunities for designing, and investigate materials, components, tools, equipment and processes to achieve intended designed solutions	**Problem scoping** • Understanding the boundaries of a problem • Clarify and restate the goal • Identify constraints • Consider problem feasibility • Add context • Experiment with materials • Establish collaboration	**Exploring and identifying** • Identify a (real world) problem based on a theme or context of interest to students - current popular topic, issue of concern or interest from community, work or study	**Engage** • Discover what was learned and connect to life
Planning and designing	**Planning and conducting** • With guidance, plan and conduct scientific investigations to find answers to questions, considering the safe use of appropriate materials and equipment • Consider the elements of fair tests and use formal measurements and digital technologies as appropriate, to make and record observations accurately	**Generating and designing** • Design a user interface for a digital system (ACTDIP018) • Design, modify and follow simple algorithms involving sequences of steps, branching	**Constructing and Design** • Model development • Sketch and design • Interpret design • Transform design to model	**Formulating and planning** • Formulate a mathematical model to address the question (involves translating from the real-world setting to the domain of mathematics, making simplifying assumptions, choosing variables, estimating magnitudes of inputs etc)	**Apply** • Apply what was learned to similar or different situations
Design and Development	**Explore** • Provide experience of the phenomenon or concept. • Explore and inquire into students' questions and test their ideas. • Investigate and solve problems	**Developing mental models** • Develop stronger mental models that ultimately make students better software engineers. • To use computational thinking approach to be useful and effective in a broader range of disciplines.	**Create** • Carry out the plan; create the design. • Designed solution testing (and opportunity for design failure)	**Employing and applying maths** • Employ mathematical concepts, facts, procedures and reasoning (reasoning, argumentation, manipulation and computation) to solve the problem in the	**Experience** • Do the activity
Analysing and explaining for Implementation	**Explain** • Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon. • Construct multi-	**Producing and implementing** • Select appropriate materials, components, tools, equipment and techniques and apply safe	**Redesigning and Reconstructing** • Review first design • Sketch second design • Transform design to model	**Interpreting and evaluating** • Interpret and evaluate the mathematical outcomes (interpretation, justification, and explanation) and	**Process** • Analyse and reflect upon what happened

	modal explanations and justify claims in terms of the evidence gathered • Compare explanations generated by different students/groups • Consider current scientific explanations	procedures to make designed solutions		review the mathematical results in terms of their real world meanings	
Evaluation and Supervision	**Evaluate** • Provide an opportunity for students to review and reflect on their own learning and new understanding and skills • Provide evidence for changes to students' understanding, beliefs and skills	**Evaluating** • Negotiate criteria for success that include sustainability to evaluate design ideas, processes and solutions	**Design evaluation** • Meeting constraints • Test model • Check constraints • Assess goal attainment	**Reflecting** • Critique and identify the limits of the model used to solve a problem and make a judgment as to the adequacy of the solution to the original question(s)	**Troubleshoot** • Diagnose and troubleshoot ideas on prototypes based on simulations or tests

VI. DISCUSSION

Developing a new curriculum requires large efforts, resources, and involves several changes. The first step including selecting one of the two curriculum frameworks or merging the both; rewriting and state the related curriculum documents; retraining the teachers in the integrated curriculum structure; rewritting new textbooks for possibly all grades; and providing substantial professional development course to allow school districts to coordinate pedagogy. Long-term investment in developing and refining their own robotics STEM programs has caused states, school districts, and teachers to modify their existing curriculum frameworks and have attempts to adopt national or state content standards and frameworks.

To outline the learning activities based on an integrated STEM curriculum, the selection of a topic within the curriculum for the application of educational robotics is a very important step to ensure that learning outcomes relate directly to the curriculum. The course syllabus could be modified to suit the robotics related activities but without deviating away from the objectives of the course. Next, a clear set of learning outcomes must be derived from the STEM syllabus and aligned with the STEM curriculum as a guide in the process of constructing the robotics project which will be the basis for the activities. To design the robotics projects and specification, the project requirements must be defined in a way that its completion would fulfil the learning outcomes. In addition, the requirements must resemble a real-world problem which clearly defines the type of new knowledge to be learned, whether this new knowledge comes at the core of the curricula, and what existing knowledge is necessary for students to get involved in the robotics project.

As some of the projects including a robotics competition, a set of well-defined competition rules is included. The rules and regulations must include project themes, winning criteria, ranking procedures, violations, policies, and other related terms. Finally, the assessment method for learning outcomes is design based on the Taxonomy Bloom. Assessing the learning outcomes of the integrated STEM curriculum using educational robotics is not an difficult task. The teacher can easily determine that through interviews or presentations, or even using traditional examinations.

VII. CONCLUSION

More Malaysian schools are now geared towards 21st century learning environment with emphasis on more active student-centred learning applying Higher Order Thinking Skills (HOTS) in curriculum, assessment, and co-curricular activities, and the utilisation of Information, Communication and Technology

(ICT), in preparation for the changing landscape of higher education and future opportunities. Curriculum integration requires a shift in the traditional role of the teacher to a more dynamic, interactive, and collaborative students-centered. learning environment. It requires teachers to share decision making and the complicated process of inquiry, where the outcomes are unknown. As emphasized in the Malaysia Education Blueprint 2013-2025 [19], jobs of the future are STEM jobs. The Ministry of Education contributed in sharing knowledge and expertise on curriculum, pedagogy and assessment for STEM to strengthen the regional capacity of member countries in Africa, Asia and the Pacific. Teachers in a conventional setting did not have adequate tech resources to inspire students to break free from monotonous educational pattern and would follow the same old practice for years. Various strategies can be planned to engage students and stimulate their interest in school with the aid of emerging and modern technology tools. Students would feel encouraged and empowered to participate in classroom activities with free access to such tech tools in the 21st cenruty classroom.

With the STEM-focused curriculum using educational robotics, we seek to create environments where learning happens in a hands-on and motivational way – helping students discover their talents and cement learning from the core classroom. By offering student-driven and easy-to-use materials, the new framework can reinforce and enhance the learning occurring throughout the school day, setting the secondary school students on a path to future success. Students will enjoy more inquiry-based learning in STEM curriculum through hands-on approach and the enhancement of practical sessions with more enquiry-based learning. The new curriculum focuses more on problem solving skills, and moves away from rote learning methods. It is expected that the outcome of the new robotics STEM curriculum is the graduates with skills which are critical in the 21st century such as technological literacy , collaborative and communication skills are embedded in the curriculum [20].

In the integrated STEM curriculum, whether learning about robots or learning with robots, it is essential that a robotics lesson provide an introduction to the key areas of STEM while focus to insight the students' engagement and exploration in the multidisciplines study. It is important that the curriculum allow for single activity or lesson plans as well. To allow for this, the robotics curriculum should allow entry points at various stages in the overall academic curriculum. By no means, robotics STEM curriculum is a new silver bullet for 21st century education, nor is it intended to replace the existing science and mathematics curriculum, it is another entry in the teachers' toolbox with the aim to prepare the STEM workforce and STEM literate society for the real world in Industry 4.0.

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REFERENCES

[1] K. Schuster, K. Groß, R. Vossen, A. Richert, and S. Jeschke, "Preparing for industry 4.0 – collaborative virtual learning environments in engineering education," Autom. Commun. Cybern. Sci. Eng. 2015/2016, no. June, pp. 417–427, 2016.

[2] A. Khanlari, "Effects of robotics on 21st century skills," Eur. Sci. Journal, ESJ, vol. 9, no. 27, pp. 26–36, 2013.

[3] A. Eguchi, "RoboCupJunior for promoting STEM education, 21st century skills, and technological advancement through robotics competition," Rob. Auton. Syst., 2015.

[4] M. Ministry of Education, "Blueprint 2013-2025," 2016.

[5] M. Ucgul and K. Cagiltay, "Design and development issues for educational robotics training camps," Int. J. Technol. Des. Educ., vol. 24, no. 2, pp. 203–222, 2014.

[6] A. Felicia and S. Sharif, "A review on educational robotics as assistive tools for learning mathematics and science," Int. J. Comput. Sci. Trends Technol., vol. 2, no. 2, pp. 62–84, 2014.

[7] M. A. H. Bunyamin, "STEM education in Malaysia : An assessment perspective," no. April, 2016.

[8] Ministry of Education Malaysia MOE, "Malaysia education blueprint 2015-2025 (Higher Education)," Minist. Educ. Malaysia, vol. 2025, p. 40, 2015.

[9] K. M. Meyrick, "How STEM education improves student learning," Meridian, vol. 14, no. 1, pp. 1–5, 2011.

[10] S. Han, R. Capraro, and M. M. Capraro, "How science, technology, engineering, and mathematics (STEM) project-based learning (Pbl) affects high, middle, and low achievers differently: the impact of student factors on achievement," Int. J. Sci. Math. Educ., vol. 13, no. 5, pp. 1089–1113, 2014.

[11] Norman, "Integrative Stem: Design and implementation of an 8th grade technology curriculum (Research to Practice)," 2014.

[12] G. Issa, S. M. Hussain, and H. Al-Bahadili, "Competition-based learning," Int. J. Inf. Commun. Technol. Educ., vol. 10, no. 1, pp. 1–13, 2014.

[13] J. Biggs and K. Collis, "Towards a model of school-based curriculum development and assessment using the SOLO taxonomy," Aust. J. Educ., vol. 33, no. 2, pp. 151–163, 1989.

[14] R. W. Bybee, J. a Taylor, A. Gardner, P. Van, J. C. Powell, A. Westbrook, N. Landes, S. Spiegel, M. M. Stuhlsatz, A. Ellis, H. Thomas, M. Bloom, R. Moran, S. Getty, and N. Knapp, "The BSCS 5E instructional model: Origins and effectiveness. A Report prepared for the office of science education and national institutes of health," Science (80-.)., no. June, 2006.

[15] L. Bell, "Technology literacy," no. February, pp. 20–26, 2016.

[16] PISA, "PISA 2015 results in focus," Oecd, p. 16, 2016.

[17] L. D. English and D. T. King, "STEM learning through engineering design: fourth-grade students' investigations in aerospace," Int. J. STEM Educ., vol. 2, no. 1, p. 14, 2015.

[18] Y. D. Specialist, "4-H robotics curriculum lego NXT robot 4-H robotics curriculum," no. August, 2014.

[19] M. of Education, "Malaysian education blueprint report (2013-2015)," Minist. Educ., 2016.

[20] R. Sharifah Nadiyah, H. Hanipah, and S. Faaizah, "21st century core soft skills research focus for integrated online project based collaborative learning model," J. Appl. Sci. Agric., vol. 9, no. 11, pp. 63–68, 2014.