ADAPTIVE LEARNING MODEL FOR LEARNING COMPUTATIONAL THINKING THROUGH EDUCATIONAL ROBOTIC

NURUL NAZIHAH JAMAL

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Philosophy

School of Computing
Faculty of Engineering
Universiti Teknologi Malaysia

DECEMBER 2021

DEDICATION

Bismillah. This thesis is dedicated to ayah and ma, who are responsible for convincing me to pursue my study and fight for my ambition. Their endless support and encouragement have accompanied me throughout my master journey. Besides them, I would like to dedicate this thesis to my only supervisor since my bachelor's degree, Prof. Dr. Dayang Norhayati Abang Jawawi, for countless hours spent in sharing understanding and knowledge in research.

ACKNOWLEDGEMENT

In the Name of Allah, The Most Gracious and The Most Merciful.

First and foremost, all praise to The Almighty, all praise to Allah for granting me high patience and strength to complete my master study journey of almost two years of effort and tears. I should thank many people that have made this journey such a truly priceless experience. In preparing this thesis, I was in contact in many people, researchers, academicians, teachers, and students. They have contributed towards my understanding and thoughts.

My sincere appreciation to my supervisor, Prof. Dr. Dayang Norhayati Abang Jawawi and my co-supervisor, TS. Dr. Rohayanti Hassan, for their informative supervision, guidance, valuable comments, motivation, and countless hours of time spent in sharing anything related to my study. I am so satisfied to have gained immense knowledge from them. I must not forget my close friends that also should be recognized for their great support, El, Irsyad, Meryl, Ain, Kak Yong, Zainab, Mirza, Aimi, and many more. Finally, I am grateful to all my family members.

"My dearest dad, mum, family, and friends" This is for all of you.

ABSTRACT

Computational thinking (CT) has been promoted worldwide by educational systems and is an essential skill for technological citizens. In delivering CT, various kinds of educational tools were developed by researchers to support the learning. One of the attractive tools in providing the CT is educational robotic (ER). However, delivering CT to students through ER has many challenges. There is a lack of studies presenting the general view on the integration of ER and CT as both subjects have big scope in terms of teaching and learning. Thus, this study designed a conceptual data model to represent the relationship between CT and ER. In addition to the complexity in determining the suitability of both subjects for students' learning, students also have differences in their personal traits, resulting in different learning styles and thinking styles. Therefore, this study aimed to enhance an adaptive learning (AL) model for students, which is based on the students' learning style and knowledge level. The enhanced AL model comprised three sub-models: domain model, student model, and adaptation model. Two case studies were selected, which are learning advance of CT and the introductory of computational thinking through educational robotic (CTER). At the end of the study, it can be observed that the enhanced AL model produced positive results in performance and perception for various student categories. In learning advanced CT, both groups of students exhibited a positive perception of using the AL model. Nevertheless, the group of students who applied the enhanced AL model outperformed the other group in term of performance. Additionally, in learning CTER, it can be observed that students had a good perception in using enhanced AL model, while the group of students who either applied AL model or did not in learning CTER introduction had a good result towards the learning performance. In conclusion, this study showed that the enhanced AL model could improve learning performance, especially for learning advanced CT and can be used for learning CTER.

ABSTRAK

Pemikiran komputasional (CT) telah diperkenalkan di seluruh dunia melalui sistem pendidikan dan merupakan kemahiran penting bagi warga teknologi. Dalam menyampaikan CT, pelbagai jenis alat bantuan pendidikan telah dibangunkan oleh para penyelidik untuk menyokong pembelajaran. Salah satu alat bantuan yang menarik dalam menyampaikan CT adalah pendidikan robotik (ER). Walau bagaimanapun, menyampaikan CT kepada pelajar melalui ER mempunyai banyak cabaran. Terdapat kekurangan kajian yang mengemukakan pandangan umum tentang integrasi ER dan CT kerana kedua-dua subjek ini mempunyai skop yang besar dari segi pengajaran dan pembelajaran. Oleh itu, kajian ini mereka bentuk model data konseptual untuk mewakili hubungan antara CT dan ER. Di samping kerumitan dalam menentukan kesesuaian kedua-dua subjek untuk pembelajaran pelajar, pelajar juga mempunyai perbezaan sifat peribadi mereka yang menyebabkan gaya pembelajaran dan pemikiran berbeza. Oleh itu, kajian ini bertujuan untuk menambah baik model pembelajaran adaptif (AL) untuk pelajar berdasarkan gaya pembelajaran dan tahap pengetahuan pelajar. Model AL yang ditambah baik mempunyai tiga sub model: model domain, model pelajar dan model adaptasi. Dua bentuk kajian kes telah dipilih iaitu pembelajaran CT lanjutan dan pembelajaran pengenalan pemikiran komputasional melalui pendidikan robotik (CTER). Pada akhir kajian, dapat diperhatikan bahawa model AL yang telah ditambah baik menghasilkan keputusan yang positif dalam prestasi dan persepsi untuk pelbagai kategori pelajar. Dalam pembelajaran CT lanjutan, kedua-dua kumpulan pelajar menunjukkan persepsi yang positif terhadap penggunaan model AL. Namun begitu, kumpulan pelajar yang menggunakan model AL yang telah ditambah baik mengatasi kumpulan lain dari segi prestasi. Di samping itu, dalam pembelajaran CTER, dapat diperhatikan bahawa pelajar mempunyai persepsi yang baik dalam menggunakan model AL yang ditambah baik, manakala kumpulan pelajar yang sama ada menggunakan model AL atau tidak dalam pembelajaran pengenalan CTER mempunyai keputusan yang baik terhadap prestasi pembelajaran. Kesimpulannya, kajian ini mendapati model AL yang ditambah baik dapat meningkatkan prestasi pembelajaran terutamanya untuk pembelajaran lanjutan CT dan boleh digunakan untuk pembelajaran CTER.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AL	-	Adaptive Learning
AL1	-	Adaptation Level 1
AL2	-	Adaptation Level 2
ANA	-	Activity Navigation Agent
AI	-	Artificial Intelligence
AR	-	Augmented Reality
BN	-	Bayesian Network
CAP	-	Content Adjusting Principle
CDM	-	Conceptual data model
CGPA	-	Cumulative Grade Point Average
CT	-	Computational Thinking
CTER	-	Computational Thinking through Educational Robotic
DC	-	Dependencies Configuration
DMR	-	Domain Model Repository
EA	-	Extracurricular Activities
EALM	-	Enhancement of Adaptive Learning Model
EL	-	Education Level
ER	-	Educational Robotic
FL	-	Formal Learning
FSLSM	-	Felder Silverman Learning Style Model
GTA	-	Grounded Theory Analysis
HE	-	Higher Education
HOT	-	Higher Order Thinking
ILS	-	Index Learning Style
K	-	Kindergarten
KL	-	Knowledge Level
KLSM	-	Kolb’s Learning Style Model
KPM	-	Ministry of Education
KSA	-	Knowledge Assessment Agent
LE	-	Level of Education / Education Level

LMR	-	Learning Material Repository
LMS	-	Learning Management System
LOM	-	Learning Object Metadata
LOT	-	Lower Order Thinking
LR	-	Literature Review
LRepo	-	Learning Repository
LSA	-	Learning Style Automation
LS	-	Learning Style
LSQ	-	Learning Style Questionnaire
LS1	-	Learning Style by FSLSM
LS2	-	Learning Style by KLSM
MKN	-	National Security Council
MNA	-	Material Navigation Agent
MoHE	-	Ministry of Higher Education
NBa	-	Naïve Bayes Algorithm
NRC	-	National Robotic Competition
PG	-	Postgraduate
PL	-	Personalized Learning
PS	-	Primary School
QAC	-	Question Address Code
QBR	-	Question Bank Repository
SE	-	Standard Error
SERG	-	Sofware Engineering Research Group
SMS	-	Systematic Mapping Study
SNA	-	Smart Navigation Agent
SLR	-	Systematic Literature Review
SOP	-	Standard Operating Procedure
SS	-	Secondary School
STEM	-	Science, Technology, Engineering and Mathematic
UG	-	Undergraduate
UTM	-	Universiti Teknologi Malaysia
UTMSPACE	-	School of Professional and Continuing Education
VEnVi	-	Virtual Environment Interaction

VR	-	Virtual Reality
4IR	-	The Fourth Industrial Revolution

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Overview

The Fourth Industrial Revolution (4IR) is upon us. The experts predict more than 7,000,000 jobs will be affected in the next five years in the world's largest economies especially in technological fields such as robotics, autonomous vehicles and many more (IEEE, 2020). The changes of 4IR technologies have forced the employment landscape to undergo a massive shift on selecting only those employees with advanced skills. The Thrivent 4IR demanded highly specialized skills to be driven in todays' world workforce (Chidera, 2020).

One of the skills is the ability in solving problems. Problems can be either complex or non-complex. A problem can be only tackled if the solver understands and knows the ways in which it could be solved (Rutgers, 2020). It is imperative for us to educate the youth and the working adults to develop well in this computational world. Consequently, computational thinking (CT) skills can be nurtured to help them in solving the problems in a systematic way (Wing, 2006).

CT skills are known as a fundamental skill that is suitable for everyone in developing the ability to solve problems (Wing, 2006). The skills mapped the understanding of human behaviours into the concepts of computer science such as logical and algorithmic thinking, modelling, problem-solving and many more (Beecher, 2017). CT is not just applicable in computer field but in a range of subject areas such as art, mathematics and many more (Barr and Stephenson, 2011).

For instance, CT to a computer scientist is shown by studying the algorithms and applications to different software or hardware problems while to a mathematician, it might mean by carrying out long division factoring or doing carries in addition or subtraction. In different perspective, CT skills encourages learners to consider how they can leverage technologies or methods to aid them in solving problems.

In addition, Wing (2008) suggested that CT needs to be understood and applied for all levels of education. However, this resulted in a challenge on choosing the suitability of CT concepts on what should be learned and applied. Also, in fostering the improvement of CT skills, the use of pedagogical tools to support knowledge was suggested (Grover and Pea, 2013). There are numerous open educational tools and instruments designed to assist the learners to the encouragement of CT skills development.

In recent years, robotics has seen the greatest development and implementation as a pedagogical tool. An analysis of the trends in the use of pedagogical tools has been made. The result shows that most researchers explained that the main purpose of the uses of the robotics are to attract the excitement of the learners in learning particular subjects as the learners are able to play and interact with the robots (Androutsopoulus et al., 2018; Atmatzidou and Demetriadis, 2016). They did not stated that CT has become the outcome of the study but it can be seen that the CT able to be a part as the outcomes. The analysis of the trends in the use of pedagogical tools is described in Appendix A.

Robotics are widely used in education for teaching and learning. Commonly known as educational robotics (ER), ER is able to be used in recognizing CT through problem solving activities. ER is believed to aid the learners to understand CT Skills better. Many researchers also have studied how to nurture the CT skills of the youth through educational robotics in recent decades. However, many things need to be considered when designing and constructing the integration (Pears et al., 2007).

1.2 Research Background

The suitability of CT concepts remains a question about what should be learned across the continuum of subjects at the different levels of learning (Duncan, Bell, and

Atlas, 2017). Most researchers commonly consider the basic concepts to be nurtured to the students such as abstraction, algorithmic thinking, pattern recognition, and decomposition through problem-solving activities. Furthermore, Malaysia has introduced the basic of CT Skills in the national school syllabus (Malaysia, 2019). However, there remains a challenge in proving the success of the students' perception and understanding of the CT skills learning.

A pilot survey focused on secondary school students in Johor, Malaysia in 2019 (see Appendix B) to investigate their comprehension and familiarity on the CT concept. Most of the students claimed that they were not familiar with the CT concepts. CT has been promoted to be a part of a standard curriculum for the school level in Malaysia since 2016 (Soon and Mustafa, 2018). Survey results indicated that the students had a limited understanding of the CT concepts.

Many pedagogical tools and activities have been designed and developed which included Augmented Reality (AR), Virtual Reality (VR) technologies. Researchers (Hodhod et al., 2013; Yang, 2019) designed a pedagogical tool with AR integration to engage the learner's awareness with the technologies besides claiming that the development effort helps the learners to understand CT. There are also researchers that applied virtual reality in delivering CT skills (Parmar et al., 2016). They designed an embodied interaction in virtual environments to enhance CT skills into learners by developing an edutainment application called Virtual Environment Interactions (VEnVI) (Parmar et al., 2016).

Even so, in learning and understanding the CT concepts better and suitable for every level of education, most researchers took initiatives to deliver the CT concepts through ER. Due to the revolution of technologies, there are many types of ER available for teaching and learning. ER is also able to provide a high impact in the future by involving students in technology which followed the 4IR demand (Eguchi, 2014). ER can be an interactive pedagogical tool to help the students become involved in problem-solving activities.

ER as the supporting tool to nurture CT concepts also resulted in a challenge as both subjects have a bigger scope in learning and learner context. Many sources of CT and ER have been developed and designed by researchers and developers for multi-level of education in recent years. However, most of the current technologies of ER do not explicitly state that CT concepts could become a part of the learning outcomes.

Recently, ER is most focused to present their functionalities and let the students learn the robots in an interactive way. For instance, Witherspoon et al. (2017) promote the uses of robotic functionalities such as line following function to the students through robotic programming subject domain. They also have engaged has engage students to the CT concepts during problem solving activities indirectly as they need to design solution in solving the problems. There is lack of studies that show a general view on the integration of both subjects in solving problems.

Besides that, by considering few facets such as different level of knowledge and education, not all kinds of ER are able be used generally as pedagogical tools (Lopez-Rodriguez and Cuesta, 2016). There are ER suitable for kindergarten level and ER considered too advanced for that level. This is similar to the issue faced by CT domain. There are CT concepts that are too advanced for the students regarding their age and logical thinking skills (Atmatzidou and Demetriadis, 2016). This bottleneck issue can be controlled by personalizing the learning as an uncontrolled learning may influence the results of the study in achieving the goals.

Thus, researchers commit greater effort in developing more information on how to provide suitable material for the students based on the differences in personal traits. A recent learning environment has presented two potential services in serving a personalized support in learning, which are personalized learning (PL) and adaptive learning (AL). PL is being promoted as a way of transforming the educational system by tailoring the learning pace and content to individual students (Lee, 2014) while AL is an approach to enhance the benefit of learning by adapting information delivery to individuals according to their personal behaviour and knowledge (Ishak, 2016).

Both AL and PL have commonality in the characteristics, whereas the prior knowledge of individual learners is a must to indicate the suitable path for learners in learning. However, AL has the outstanding role in helping to evaluate the learners' experiences during learning compared to PL (Neelakandan, 2020). AL is also able to re-modify the learning path of the learners according to their learning progress. Neelakandan (2020) suggested to consider AL to deliver a better learning experience as AL also considered the PL elements.

Many AL models have been proposed (Mahnane et al., 2013; Ishak, 2016; Ennouamani et al., 2019) to provide effective learning environment and materials based on adaptive features that are mapped with the personal traits such as learning style and knowledge level. The AL is able to provide them the suitable materials regarding their personal traits and improve their motivation in learning. AL model is also proven to be able to help the students in improving their learning performance by measuring the students' understanding towards the subject through assessments (Mahnane et al., 2013; Eryilmaz and Ahmed, 2017). The study by Ishak (2016) also observed that the students have a positive perception in using AL environments in learning.

However, regarding the domain of this study, there is still no direct study or development of AL model that focused on learning CT through ER (CTER). Thus, implementing adaptive learning model to ease the students' learning for CTER remains questionable. Even so, the existing AL model also can be referred to investigate the extent of this study review to support and fulfil the requirements on providing best learning materials and activities while improving the performances of the students towards the topics learned.

1.3 Problem Statement

Delivering CTER to students is challenging. First, there is complexity in determining the suitability of CT concepts to be learned or taught at different levels of education and knowledge as there are many kinds of CT concepts introduced by the researchers**.** Furthermore, the recent ER developments did not specifically define CT skill development as a part of the learning goals. Thus, this study presents the integration of CT and ER. Also**,** the revolution of ER and CT causes the development of various contents and materials which might pose difficulties considering the demography of the students.

Along with that, to deliver the CTER effectively, adaptivity aspects in learning must be used to personalize the material that is appropriate for the students' tastes. However, there has been no direct study or development for the deployment of the AL model in any associated themes for learning CTER. As a result, there is a need to research and evaluate the effects of the AL model in learning CTER. The following are the general research questions that this study attempts to answer:

"*How can the learning of CT through ER (CTER) be nurtured using an AL model?"*

To answer this question, a set of research questions can be derived and defined as follow:

(a) What are the bottlenecks or issues to attain CT core principles through ER?

(b) Can all the concepts in CT be attained through ER activities?

(c) Can AL model address the bottlenecks or issues in (c)?

(d) How can the AL model be enhanced by providing the learning material and activity adaptively?

(e) How to evaluate the AL model in (e)?

1.4 Research Aim and Objectives

The aim of this research is to propose an enhancement of adaptive learning model which gives focus to CTER learning. This research further investigates the students' performance and perception in using AL model for CTER learning. The aim of the study is derived to research objectives which are as follows:

(a) To enhance the adaptive learning model by providing learning activity and material adaptively based on different background of learners.

(b) To apply the enhanced adaptive learning model in learning CTER.

(c) To evaluate and investigate the students' performance in applying adaptive learning model on learning CTER.

1.5 Scope of the Research

In this research, the scope of the study is defined as follows:

(a) RoboKar is chosen as the pedagogical tool for CTER learning.

(b) Two experiments are conducted to achieve different objectives. First experiment to achieve the first objective involves undergraduate students from UTM, Johor to investigate the improvement of performances in applying the enhanced model of AL as compared to the current AL model. The second experiment will involve secondary school students from Dun Kemelah, Segamat, Johor to investigate the uses of adaptive learning model in learning CTER to achieve the second objective.

(c) For the first experiment, this study covers the advanced concepts of CT through Data Structure and Algorithm Course.

(d) For the second experiment, this study only covers the basic concepts of CT along with the ER activities including the abstraction, decomposition, algorithmic thinking, pattern recognition and test and debugging concepts.

(e) For adaptivity elements, three adaptive features are covered, which are knowledge level of students (Pass or Fail), learning style from Felder Silverman Learning Style Model (FSLSM) and learning style from Kolb

Learning Style Model (KLSM). This study only covers two dimensions from both learning styles whereas FSLSM measured visual and verbal persona while KSLM measured theorist and pragmatist persona. The selected dimensions are based on the availability resources from the current AL model and the suitability to meet the research requirements.

1.6 Significance of Research

Finding from this research will contribute to the understanding of how ER can be integrated into CT skills in solving problem. The presentation of the relationship of CT and ER is able to list the elements or factors needed to be considered before delivering CT through ER. Also, the relationship between CT and ER can explained and shows that CT can become part of the outcomes in learning ER. In addition, the benefits of robotics in education fields can be positively revealed which can help in fostering innovation into youth and not only focus on promoting the ER functionalities.

This study also gives benefits to the students as they can get suitable learning material and content for them based on their own preferences, which focus on their background of knowledge and style of learning. However, the other persona such as teachers or the curriculum designer of the school can also benefit from this study, such as the conceptual view on nurturing CT through ER. This study also benefits the software engineering community who are planning, designing, or revising a new framework or platform in nurturing CT while attracting the interest of students to robotics in this era of 4IR.

1.7 Thesis Organization

This research includes six chapters. Chapter 1 presents the overview concerning this research. The important issues revolving the area of interest are also discussed. The aim, objectives, scope, and the significance of the study are also presented. Chapter 2 provides deeper understanding on the area of interest. The past literatures that employed various methods are presented. Justification on the needs to improve on the existing methods are also discussed. Chapter 3 presents the methodology design for this research. This chapter are provided details of the proposed techniques and measurement for this research. Chapter 4 explained how the adaptive learning model is developed and can be implemented and the integration of the CT and ER into the proposed adaptive learning model is presented. Chapter 5 also described the evaluation result of the case study. Finally, the summarization of the work conducted within this thesis, the contribution of the research, the research limitations and the direction of the future works are provided in Chapter 6.

REFERENCES

Aguar, K., Safaei, S., Arabnia, H. R., Gutierrez, B. J., Potter, W. D., & Taha, T. R. (2018). Reviving Computer Science Education Through Adaptive, Interest-Based Learning. *International Conference on Computational Science and Computational Intelligence* (pp. 1161-1166). IEEE.

Ahmad, M. F., & Wan Abdul Ghapar, W. G. (2019). The Era of Artificial Intelligence in Malaysian Higher Education: Impact and Challenges in Tangible Mixed-Reality Learning System toward Self Exploration Education (SEE). *16th International Learning & Technology Conference 2019* (pp. 2-10). Elsevier.

Alamo, J., Quevedo, E., Coll, A. S., Ortega, S., Fabelo, H., Callico, G. M., & Zapatera, A. (2021). Sustainable Educational Robotics. Contingency Plan During Lockdown in Primary School. *Sustainability,* 8388.

Alshammari, M., Anane, R., & Hendly, R. (2015). An E-Learning Investigation into Learning Style Adaptivity. *The 48th Hawaii International Conference on System Sciences* (pp. 11-20). USA: IEEE.

Ambrose, S. A., Bridges, M. W., DiPietro, M., Lovett, M. C., & Norman, M. K. (2010). *How Learning Works: Seven Research-Based Principles for Smart Teaching.* San Francisco: Google Books.

Androutsopoulus, K., Aristodemou, L., Boender, J., Bottone, M., Currie, E., El-Aroussi, I., . . . Weldin, N. (2018). MIRTO: an Open-sources Robotic Platform for Education. *ECSEE'18* (pp. 55-62). Germany: ACM.

Angeli, C., Voogt, J., Fluck , A., Webb, M., Cox, M., Malyn-Smith, J., & Zagami, J. (2016). A K-6 Computational thinking curriculum framework-Implications for teacher knowledge. *Journal of Educational Tehnology & Society, 19*(3), 47-57.

Aristawati, F. A., Budiyanto, C., & Yuana, A. R. (2018). Adoptiong Educational Robotics to Enhance Undergraduate Students' Self-Efficiacy Levels of Computational Thinking. *Journal of Turkish Science Education,* 42-50.

Atmatzidao , S., & Demetriadis, S. (2016). Advancing Students' Computational Thinking Skill Through Educational Robotics. A study on age and gender relevant differences. *Robotics and Autonomous Systems*, 661-670.

Bajaj , R., & Sharma, V. (2018). Smart Education with artificial intelligence based determination of learning styles. *International Conference on Computational Intelligence and Data Science (ICCIDS 2018)* (pp. 834-842). Elsevier.

Barr, V., & Stephenson, C. (2011). Bringing Computational Thinking to K-12-What is Involved and What is the role of the computer science education community. *ACM Inroads*, *2*(1), 48-54.

Battou, A. (2011). Towards an adaptive learning system based on a new learning object granularity approach . *International Journal of Advanced Computer Science and Applications*, 8-13.

Beecher, K. (2017). *Computational Thinking : A beginner's guide to problem solving and programming.* UK: BCS Learning & Development Ltd.

Bers , M. U., Flannery , L., Kazakoff, E. R., & Sullivan, A. (2014). Computational Thinking and Thinkering- Exploration of an early childhood Robotics curriculum. *Computers & Education*, 146-157.

Bontchev, B., & Vassileva, D. (2011). Learning Objects Types Dependability on Styles of Learning . *WSEAS* (pp. 227-234). WSEAS On-Line Proceedings.

Brennan, K., & Resnick, M. (2012). New frameworks for studying and assessing the development of computational thinking. *In proceeding of the 2012 Annual Meeting of the American Educational Research Association* (pp. 1-25). Vancoucer, Canada: Harvard Edu.

Cassidy, S. (2004). Learning Styles: An overview of Theories, Models and Measures. *Educational Psychology*, 419-444.

Chalmers, C. (2018). Robotics and Computational Thinking in Primary School. *International Journal of Child-Computer Interaction*, 93-100.

Cheong, L. S. (2014). *Adaptive Tutorial System for Learning Mathematic among Form 1 Students.* Skudai, Johor: Universiti Teknologi Malaysia.

Chetty, J. (2015). Lego Mindstorms: Merely a Toy or a Powerful Pedagogical Tool for Learning Computer Programming. *Conferences in Research and Practice in Information Technology Series (2015)* (pp. 27-30). Sydney: ResearchGate.

Chidera, U. (28 Sept, 2020). *Top 10 Skills You Need to Thrive in the 4th Industrial Revolution.* Retrieved from After School Africa:

https://www.afterschoolafrica.com/51364/top-10-skills-you-need-to-thrive-in-the-4th-industrial-revolution/#:~:text=The%20fourth%20industrial%20revolution%20is%20replete%20with%20sophisticated,enable%20workers%20to%20respond%20swiftly%20to%20corporate%20th

Chookaew, S., Sootkaneung, W., Wongwatkit, C., Hutamarn, S., Pratumsuwan, P., & Howimanporn, S. (2018). Enhancing High-School Students' Computational Thinking with Educational Robotics. *2018 7th International Congress on Advanced Applied Informatics* (pp. 204-208). Yonago, Japan: IEEE.

Chou, P.-N. (2019). Little Engineers: Young Children's Learning Patterns in an Educational Robotics Project. *World Engineering Education Forum - Global Engineering Deans Council (WEEF-GEDC)* (pp. 1-3). USA: IEEE.

Cielniak, G., Bellotto , N., & Duckett, T. (2013). Integrating mobile robotics and vision with undergraduate computer science. *Educations*, 48-53.

Duncan, C., Bell, T., & Atlas, J. (2017). What do the teachers think? Introducing computational thinking in the primary school curriculum. *ACM International Conference Proceeding Series*, 65-74.

Dunn, R., & Griggs, S. (2000). *Practical Approaches to Using Learning Styles in Higher Education.* Bergin & Garvey.

Educational Resources, K. (January, 2020). *Bee-Bot Robot*. Retrieved from KooKaburra: https://www.kookaburra.com.au/bee-bot-robot

Eguchi, A. (2014). Robotics as a Learning Tool for Educational Transformation. *Proceedings of 4th International Workshop Teaching Robotics, Teaching with Robotics & 5th International Conference Robotics in Education* (pp. 27-34). Padova (Italy): TERECoP Project .

El-Bishouty, M. e. (2014). Smart e-COurse Recommender Based on Learning Styles. *Journal of Computers in Education*, 99-111.

Ennouamani, S., Akharraz, L., & Mahani, Z. (2019). Integarting ICT in Education: An adaptive Learning System Based on Users' Contect in Mobile Environments. In Y. Farhaoui, & L. Moussaid, *Big Data and Smart Digital Environment* (pp. 15-19). Springer.

Eryilmaz, M., & Ahmed, A. (2017). An Adaptive Teaching Model for Flipped Classroom. *International Journal on Recent and Innovation Trends in Computing and Communication* , 35-39.

Esichaikul, V., Lamnoi, S., & Becther, C. (2011). Student Modelling in Adaptive E-Learning Systems. *Knowledge Management & E-Learning*, 342-355.

Falcinelli, F., & Laici, C. (2013). *ICT in the classroom: New Learning Environment.* Italy: Handbook of Research on Didactic Strategies and Technologies for Education: Incorporating Advancements.

Felder, R., & Silverman, L. (1988). Learning and Teaching Styles in Engineering Education. *Engineering Education*, 674-681.

Flick, U. (2009). *An Introduction to Qualitative Research.* Books Google.

Fronza, I., Corral, L., & Pahl, C. (2019). Combining Block-Based Programming and Hardware Prototyping to Foster Computational Thinking. *Proceedings of the 20th Annual SIG Conference on Information Technology Education* (pp. 55-60). ACM.

Garces, J. M., Almagro, C. V., Lunghi, G., castro, M. D., Buonocore, L. R., Prades, R. M., & Masi, A. (2021). MiniCERNBot Educational Platform: Antimatter Factory Mock-up Missions for Problem-Solving STEM Learning. *Sensors*, 1398.

Gonzalez, Y. A., & Murioz-Repiso, A. V. (2018). A robotics-based approach to foster programming skills and computational thinking- Pilot experience in the classroom of early childhood education. *ACM International Conference Proceeding Series*, 41-45.

Graf, S., & Kinshuk, K. (2006). Considering Learning Styles in Learning Management Systems: Investigating the Behaviour of Students in and Online Course. *Proceedings of the First IEEE International Workshop on Semantic Media Adaptation and Personalization* (pp. 25-30). IEEE .

Grandi, R., Falconi, R., & Melchiorri, C. (2014). Robotic Competitions: Teaching Robotics and Real-Time Programming with LEGO Mindstorms. *Proceedings of 19th World Congress, The International Federation of Automatic Control Cape Town, South Africa.* (pp. 10598 - 10603). South Africa.: ScienceDirect.

Grover, S., & Pea, R. (2013). Computational thinking in K-12 a review of the state of field. *Educational Researcher, 42*(1), 38-43.

Hamid, S. A., Admodisastro, N., Manshor, N., Ghani, A. A., & Kamaruddin, A. (2018). Engagement Prediction in the Adaptive Learning Model for Students with Dyslexia. *ACM International Proceedings Series* (pp. 66-73). ACM.

Hartman, V. (1995). Teaching and Learning Style Preferences: Transitions Through Technology. *VCCA Journal*, 18-20.

Hodhod, R., Fleenor, H., & Nabi, S. (2014). *Adaptive Augmented Reality Serious Game to Foster Problem Solving Skills.* Retrieved from CSU ePress: https://csuepress.columbusstate.edu/bibliography_faculty/49

Hollweck, T. (2016). Case Study Research: Design and Methods. *Canadian Journal of Program Evaluation*, 282.

Honey, P., & Mumford, A. (1992). *The manual of Learning Styles.* Google Books.

Idris, N., Yusof, N., & Saad, P. (2009). Adaptive Course Sequencing FOr Personalization of Learning Path Using Neural Network. *International Journal of Adavances in Soft Computing and Its Applications*, 49-61.

IEEE. (2020). *What is the Fourth Industrial Revolution.* IEEE Innovation.

Ishak, M. K. (2016). *Enhancement of Learning Management System with Adaptive Features.* Malaysia: Universiti Teknologi Malaysia.

Jamal, N. N., Jawawi, D. N., Hassan, R., & Riadz, I. K. (2020). Adaptive Learning in Computing Education: A Systematic Mapping Study. *International Conference on Applied Computing* (p. 012069). Bangkok: IOP Conference Series: Materials Science and Engineering.

Jawawi, D. N., & Mamat, R. (2009). Teaching Embedded Real-Time Programming Using Autonomous Mobile Robots for Undergraduates in Computer Sciences. *International Conference on Control, Instrumentation and Mechatronics Engineering (CIM 2009)* (pp. 236-240). Malaca: UK Simulation Society.

Jawawi, D. N., Mamat, R., Ridzuan, F., Khatibsyarbini, M., & Zaki, M. (2015). Introducing computer programming to secondary school students using mobile robots. *Control Conference (ASCC), 2015 10th Asian* (pp. 1-6). Johor: IEEE.

Kalelioglu, F., Gulbahar, Y., & Kukul, V. (2016). A framewok for computational thinking based on a systematic research review. *Baltic Journal of Modern Computing*, 583-596.

Kao, W. C., & Hsu, T. C. (2019). Learning Computational Thinking without a computer- How computational Participation Happens in a Computational Thinking Board Game. *The Asia-Pacidic Education Researcher*.

Keefe, J. (1987). *Learning Style: Theory and Practice.* National Association of Secondary School Principals.

Kitchenham, B., Brereton, O. P., Budgen, D., Turner, M., Bailey, J., & Linkman, S. (2008). Systematic Literature Reviews in Software Engineering - A systematic literature review. *Informating and Software Technology*, 7-15.

Kolb , D. (1984). Experiential Learning: Experience as the source of learning and development. *Englewood Cliffs, NJ: Prentice-Hall*, 21-38.

Lee, T. Y., Mauriello, M. L., Ahn, J., & Bederson, B. B. (2014). CTArcade: Computational Thinking with games in school age children. *International Journal of Child-Computer Interaction*, 26-33.

Lichtnow, D. e. (2011). Recommendation of Learning Material through Students' Collaboration and User Modeling in an Adaptive E-Learning Environment. *Technology-Enhanced Systems and Tools for Collaborative Learning Scaffolding*, 257–278.

Lopez-Rodriguez, F., & Cuesta, F. (2016). Arduino-A1: Low-Cost Educational Moile Robot Based on Android and Arduino. *Journal of Intelligent & Robotic Systems*, 63-76.

Louhab, f. E., Bahnasse, A., & Talea, M. (2017). Smart Adaptive Learning Based on Moodle Platform. *International Working Conference on Source Code Analysis and Manipulation* (p. 5). Morocco: ACM.

Mahnane, L., Laskri, M. T., & Trigano, P. (2013). A model of Adaptiv e-learning Hypermedia System based on Thinking and Learning Styles. *International Journal of Multimedia and Ubiquitous Engineering*, 339-350.

Maker Works Technology. (February 2019, 2015). *MakeBlock*. Retrieved from MakeBlock: http://learn.makeblock.com/en/

Malaysia, K. P. (2019). *Konsep Asas Pemikiran Komputasional: Buku Teks Tingkatan 1*. Malaysia: Kementerian Pendidikan Malaysia.

McLeod, S. (2017). *Kolb-Learning Styles and Experiential Learning Cycle*. Retrieved from SimplyPsychology: https://www.simplypsychology.org/learning-kolb.html

Molnar, A., & Muntean, C. H. (2009). Enhancing Domain Model with Performance Oriented Metadata for Adaptive E-Learning Systems. *10th Annual Irish Educational Technology Users' Conference. EdTech.* (pp. 1-6). Dublin: NCI Library.

Mustafa, Y. E., & Sharif, S. M. (2011). An approach to Adaptive E-Learning Hypermedia Sytem based on Learning Styles (AEHS-LS): Implementation and evaluation. *International Journal of Library and Information Sciences*, 15-28.

Neelakandan, N. (2020). *How To Differentiate Adaptive Learning And Personalized Learning In L&D.* Retrieved from Wiz Cabin: https://wizcabin.com/how-to-differentiate-adaptive-learning-and-personalized-learning-in-ld/

Noh, J., & Lee, J. (2019). Effects of robotics programming on the computational thinking and creativity of elementary school students. *Education Technology Research Development*, pages463–484.

Normadhi, A., Nizam, M. H., Shuib, Baiti, N., Bimba, Idris, . . . Vimala. (2019). Identification of personal traits in adaptive learning environment: Systematic literature review. *Computers & Education*, 168-190.

OECD. (2016). *Innovating Education and Educating for Innovation: The Power of Digital Technologies and skills, OECD Publishing, Paris.* Paris: OECD. doi:10.1787/9789264265097

Park, O. C., & Lee, J. (2003). Adaptive Instructional Systems. . *Educational Technology Research and Development*, 651-684.

Parmar, D., Isaac , J., Babu, S. V., D'Souza, N., & Leonard, A. E. (2016). Programming Moves: Design and Evaluation of Applying Embodied Interaction in Virtual Environments to Enhance Computational Thinking in Middle School Students. *IEEE Virtual Reality Conference 2016* (pp. 131-140). USA: IEEE.

Pears, A., Seidman , S., Malmi , L., Mannila, L., Adams, E., Bennedsen, J., . . . Paterson , J. (2007). A survey of literature on the teaching of introductory programming. *ACM SIGCSE Bulletin*, 204-223.

Polsani, P. (2006). Use and Abuse of Reusable Learning Objects. *Journal of Digital Information, 3*(4), 1.

Psycharis, S., Kalovrektis, K., Xenakis, A., Paliokas, I., Patrinopoulos, M., Georgiakakis, P., . . . Ntourou, V. (2021). The Impact of Physical Computing and Computational Pedagogy on Girl's Self - Efficacy and Computational Thinking Practice. *IEEE Global Engineering Education Conference (EDUCON)* (pp. 308-315). IEEE.

Repenning, A., Basawapatna, A., & Escherle, N. (2016). Computational thinking tools. *In 2016 IEEE Symposium on Visual Languages and Human-Centric Computing* (pp. 218-222). Cambridge, UK: IEEE.

Ribeiro, C. R., Coutinho, C. P., & Costa, M. F. (2011). A proposal for the evaluation of educational robotics in basic schools. *International Study Association on Teachers and Teaching (ISATT),* 832-839.

Rimbaud, Y., McEwan, T., Lawson, A., & Cairncross, S. (2015). Adaptive Learning in Computing for non-native speakers. *Proceeding Education Conference* (pp. 1-4). IEEE.

Robson, C. (2011). *Real World Research.* John Wiley & Sons.

Romero, M., Lepage, A., & Lille, B. (2017). Computational thinking development through creative programming in higher education. *International Journal of Educational Technology in Higher Education*, 1-15.

Rutgers,, T. (29 January, 2020). *What is computational Thinking*. Retrieved 3 March, 2020, from Dimacs: https://ctpdonline.org/

Sasbadi Holdings Berhad. (2020). *National Robotics Competition.* Retrieved from National Robotics Competition: http://nrc.sasbadi.com/

Sasbadi Learning Solution Sdn Bhd. (October, 2021). *Sasbadi Learning*. Retrieved from The National Robotics Competition: https://sasbadilearning.com/events/

scienceprog.com. (2021). *Building and evaluating Naive Bayes classifier with WEKA*. Retrieved from ScienceProg: https://scienceprog.com/building-and-evaluating-naive-bayes-classifier-with-weka/

Seiter, L., & Foreman, B. (2013). Modeling the learning Progressions of computational thinking of primary grade students. *In Proceedings of the 9th annual international ACM conference on International computing education research* (pp. 59-66). Auckland, New Zealand: ACM .

Selby, C. (2012). Promoting Computational thinking with programming. *In Proceedings of the 7th Workshop in Primary and Secondary Computing Education* (pp. 74-77). Hanburg, Germany: ACM.

Selby, C., & Woollard , J. (2013). *Computational Thinking: The developing Definition.* Southampthon: University of Southampton (E-prints).

Sen, C., Ay, Z. S., & Kiray, S. A. (2021). Computational Thinking Skills of gifted and talented students in integrated STEM activities based on the engineering design process: The case of robotics and 3D robot modeling. *Thinking Skills and Creativity*, 100931.

Sherman, R. (2015). *Foundational Data Modeling.* ScienceDirect.

Silva, R., Fonseca , B., Costa, C., & Martins, F. (2021). Forstering Computational Thinking Skills: A Didactic Proposal for Elementary School Grades. *Education Sciences,* 1-11.

Simko, M., Barla, M., & Bielikova, M. (2010). A Framework for Adaptive Web-Based Learning 2.0. *Advances in Information and Communication Technology*, 367-378.

Smith, M. K. (2008). *Infed*. Retrieved from Informal Learning: http://infed.org/mobi/informal-learning-theory-practice-and-experience/

Smith, M. K. (2018). *What is teaching? A definition and discussion*. Retrieved from infed: http://infed.org/mobi/what-is-teaching/

Soon, L. C., & Mustafa, J. (2018). Tahap Pemikiran Komputasional dan Hubungannya dengan Prestasi Akademik Pelajar PISMP di Sarawak. *Selangor Humaniora Review,* 33-43.

Srisangngam, P., & Dechsura, C. (2021). STEM Education Activities Development to Promote Computational Thinking's Students. *2020 International STEM Education Conference (iSTEM-Ed 2020)* (pp. 103-105). Thailand: IEEE.

Su, J. M. (2014). A Self-regulated Learning System to Support Adaptive Scaffolding in Hypermedia-based Learning Environments. *International Conference Ubi-Media Computing and Workshops*, 326-331.

Sullivan , A., & Bers, M. U. (2016). Robotics in the early childhood classroom: Learning outcomes from an 8-week robotics curriculum in pre-kindergarten through second grade. *International Journal of Technology and Design Education,* 3-20.

Wing, J. (2008). Computational Thinking and Thinking about computing. *The Royal Society (Philosophical Transactions)*(July 2008), 3717-3725.

Wing, J. M. (2006). Computational Thinking. *Communications of the ACM*, 33-35.

Witherspoon, E. B., Higashi, R. M., Schunn, C. D., Baehr, E. C., & Shoop, R. (2017). *Developing Computational Thinking Through a Virtual Robotics Programming Curriculum* . USA: ACM.

Yang, T. C., Hwang, G. J., & Yang, J. H. (2013). Development of an Adaptive Learning System with Multiple Perspectives based on Students' Learning Styles and Cognitive Styles. *Educational Technology & Society*, 185-200.

Yousef, D. A. (2018). Learning style preferences of postgraduate students: The caseof the British University in Dubai, the United Arab Emirates. *Jounal of International Education in Business*, 971-991.

Yu , H., & Fan, J. (2009). Design and Implementation of the Framework for Adaptive e-Learning System. *Proceedings of the Second International Conference on Hybrid Learning and Education* (pp. 140-149). Macau, China: Springer-Verlag.

Yudin, A., Vlasov, A., Salmina, M., & Shalashova, M. (2020). Evolution of Educational Robotics in Supplementary Education of Children. *Robotics in Education*, 336-343.

Yusob, B., & Shamsuddin, S. (2006). Knowledge Discovery through Supervised Kohonen Network to Identify Student's Knowledge Level in Adaptive Hypermedia Learning System. *Proceedings of the Postgraduate Annual Research Seminar* (pp. 224-233). IEEE.

Zaina, L. (2011). Adaptive Learning in the Educational e-LORS System: An Approach Based on Preference Categories. . *International Journal of Learning Technology*, 341-361.

Zhang , L., & Nouri, J. (2019). A systematic review of learning computational thinking through scratch in K-9. *Computers & Education*, 103607.

LIST OF PUBLICATIONS

Indexed Proceeding

Jamal, N. N., Jawawi, D. N., Hassan, R., & Kamil, R. I. (2020, May). Adaptive Learning in Computing Education: A Systematic Mapping Study. In *IOP Conference Series: Materials Science and Engineering* (Vol. 864, No. 1, p. 012069). IOP Publishing. **(Indexed by Scopus)**

Indexed Journal

Jamal, N. N., Jawawi, D. N., Hassan, R., & Mamat, R. (2021). Conceptual Model of Learning Computational Thinking Through Educational Robotic. *International Journal of Emerging Technologies in Learning*, *16*(15). **(Indexed by Scopus)**