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Exploring K-12 Students' Acceptances of a Computational Making Programme: A Case Study in Singapore

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Abstract: In this paper, we describe research conducted around a 180 hour programme designed to introduce secondary school students to computational making through app development. The quantitative data analysis indicated that most of the participating students, whether male or female, seem to have developed a high level of interest and acceptance of computational making activities. The correlational and SEM analysis indicated that although these students, from various schools, have benefited in different dimensions. Design thinking readiness and coding readiness should be highlighted as the prominent factors derived from this Computational Making Programme for students to develop their interest and make recommendations to others

Keywords: Computational Making, Computational Thinking, Interdisciplinary Readiness

1. Introduction

Singapore launched a "Digital Readiness Blueprint" in 2018 to ensure that every citizen is equipped to live in a Smart Nation and have access to the tools and knowledge to benefit from technology. This push towards digital technology aims to deepen its citizens' technical capabilities, especially in key areas such as data science, artificial intelligence and cyber security. The value of computational capabilities is highlighted in this vision and to meet this vision, the government has started introducing computational making related activities in schools. Computational making is an important skill to have in today's digital economy, especially so to meet the ever-changing global challenges and work demands (Riddle, 2015). In education, it is regarded as a key component of 21st century learning. Marenko (2015) describes computational making as an activity where computation and making come together in the digital medium through sensory participation and an understanding of materiality. Making has its origins in the works of Papert, Dewey, Piaget, and Montessori (Martinez & Stager, 2013) and its emphasis on active learning through the creation of artefacts is gaining traction in recent years (Rode, Weibert, Marshall, Aal, von Rekowski, Mimouni, & Booker, 2015). It has been suggested that making is apt for linking the digital and the physical mediums, especially in the computing field (Rosner, 2010; Buechley, Rosner, Paulos, & Williams, 2009; Mellis, Follmer, Hartmann, Buechley, & Gross, 2013). Papert, the pioneering force behind the maker movement, strongly encouraged children to use computers to invent and build various artefacts (Gershenfeld, 2007). Indeed, making should allow learners to understand the complexities and workings of technology, rather than be contented as a passive consumer of technology (Kafai et al., 2014a).

As schools start introducing computational making in the classroom, it is important to take note of some of the difficulties faced by learners. Computational making can be cognitively challenging as it is technically complex and demands both declarative and procedural knowledge (Álvarez & Larrañaga, 2016; Renumol, Jayaprakash, & Janakiram, 2009). Computational making also encompasses more than just coding – students learn skills related to problem-solving via computer science concepts like abstraction and decomposition (Lye & Koh, 2014). A review of the literature indicates that students often consider programming or computational making boring as they find the theoretical concepts and techniques too tedious and abstract (Bennedsen, Caspersen, & Kölling, 2008). Traditional didactic ways of teaching are often critiqued for their limitations in engaging the diverse learning needs of students (Benda, Bruckman, & Guzdial, 2012; Boy, 2013). It is especially difficult for students who are hands-on, less linear learners, as a didactic style tends to emphasis an analytical teaching approach that dictates that there is a right (and only) solution to a prescribed problem (Buechley, Eisenberg, Catchen, & Crockett, 2008; Grove, Jorgenson, Brummel, Sen, & Gamble, 2011). Other findings have revealed that students' difficulties stem from poor teaching methodologies and low interactivity (Barker, McDowell, & Kalahar, 2009; Coull & Duncan, 2011). The ways lessons are designed do not promote active learning and fail to offer contextual information of how the particular functions and commands are to be used (Kim & Ko, 2017).

In reviewing on the teaching and learning of computational thinking through computational making, Lye and Koh (2014) found that an effective learning environment would be one that is contextualised and most relatable to the students. For lessons to be more intellectually stimulating, students should work on an authentic problem applicable to them and create corresponding artefacts (Jonassen, 2011; Kafai & Resnick, 1996). A study by Marshall and colleagues (2010) proposed the idea of using tangible interfaces to support teaching and learning computing. In a similar vein, Kafai and Burke (2014) suggested applying the maker culture to introduce key computing concepts. Their research in demonstrated that teaching computing using e-textiles can broaden students' participation (Kafai, Lee, Searle, Fields, Kaplan, & Lui, 2014b) Similarly, Rode and colleagues (2015) discussed the benefits of computational making and examined how it could how account for a more effective way to support teaching programming in to a diverse range of students.

In this study, we describe a study conducted around a 180-hour out-of-school programme designed to introduce students to computational making through App development. The students were to develop apps based on challenge-based learning, storytelling and design thinking. The purpose of this study is to explore the effectiveness of the programme and the students' interdisciplinary perceptions and readiness through attending the programme.

2. Learning Through Computational Making

The learning theory that is widely used in learning-by-making is constructionism. Constructionism posits that the efficacy of learning is increased when learners participate in learner-led inquiry which is driven by creativity and making (Stevenson, M., Falloon, G., Forbes, A., & Hatzigianni, M, 2018). It is as Papert (1986) expounded, that a learner experiences meaningful learning by reconstructing information through the building of an artefact rather than as a passive receiver of knowledge. In that context, learning then becomes more relevant to the learner as they gain information through "learning-by-demand" rather than the traditional "just-in-case" curriculum that dispenses a syllabus that is unrelatable to the learners, just so that it might hopefully be of use later (Gershenfeld, 2007).

As a social activity, makers share resources, utilise tools that are accessible to all, working together to achieve a common objective (Tenenberg, 2018). Kafai (2016) considered the notion of participation in the social context of making as a crucial and distinct feature of computing. When learners collaborate, they learn from one another, and the exposure to an understanding of diverse perspectives leads them to solve problems in a creative manner (Kafai et al., 2014b; Kafai et al., 2014a; Lewis, 2009; Peppler, Glosson, Kafai, Fields, & Searle, 2011; Xie, Antle, & Motamedi, 2008). It takes a process of iterative design, the harnessing of a technological tool and the collaborative exchange of information for making to be meaningful (Tanenbaum, Williams, Desjardins, & Tanenbaum, 2013).

3. Method

3.1 Research Questions

Specifically, this study is guided by the following research question:

> *RQ: What are students' acceptances (in terms of recommendation and enjoyment) of the Computational Making Programme?*

3.2 Research Instrument

To address the research questions, we design a survey instrument that is to explore the effectiveness of the Programme on students using a framework that incorporates eight inter-related constructs that we have identified from the literature (Hughes, Nzekwe, & Molyneaux, 2013; Kong, Chiu, & Lai, 2018; Lim, Hosack, & Vogt, 2012; Pierce, Stacey, & Barkatsas, 2007). Two constructs are about students' acceptances of the programme including Recommendation and Enjoyment. The other six constructs are about students' interdisciplinary readiness: Interest Development, Science & Math Readiness, Design Thinking Readiness, Problem Solving Readiness, Communication & Collaboration Readiness, and Coding Readiness. To maximize measurement reliability, students were asked to indicate their level of agreement with each item on a 7-point Likert scale (1 = Strongly disagree; 7 = Strongly agree).

3.3 Research Design and Participants

We conducted a study in an after-school computational making programme where 50 secondary school students (between the ages of 13 and 16) worked on developing an app. This programme was a collaboration between a government body, an education company and a tech company. Our research took place in a training room in the tech company. This was to introduce the students to the corporate world of technology. As part of the programme, the students got to interact with other student developers and encountered first-hand experience of developing their own apps from scratch. The programme provided students with insights and skills on commercial app development, as shown in Figure 1. They had to hone the skills needed to pitch their app and on were required to navigate the different levels of brainstorming, planning, prototyping and evaluating their final product. Beyond coding, students also spent time developing skills required to pitch the app, mainly in story-telling and marketing.

During the 180-hour programme, students met every Saturday morning for 3hours each time during the school term and again for several days in June and during the September break. This programme was part of government initiative to nurture secondary school students who demonstrated an interest in computational thinking but who could not find the support or guidance they needed at school. The students were nominated by the school as they had shown interest in learning about App Development. Students did not have any background in coding. More than 70 students applied for the programme and were asked to complete a series of questions on logic and math. Out of all the applications received, 50 students (between the ages of 13 and 16) from 12 schools were selected to be part of the inaugural programme.

We have 28 responses in the survey, with 71.4% male and 28.6 % female. They are from 12 secondary school, aged from 13 to 16.

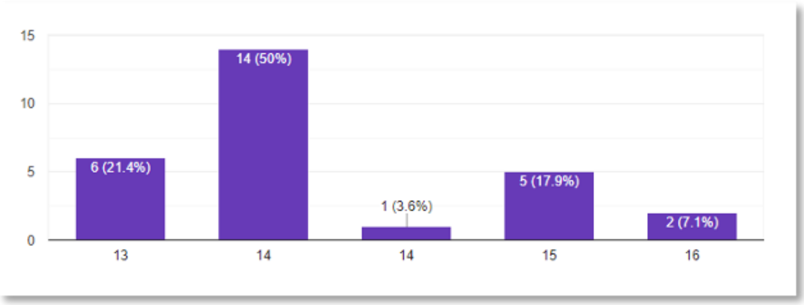

Figure 1. Age Distribution of the Participants

4. Results

4.1 *What are students' acceptances (in terms of recommendation and enjoyment) of the Computational Making Programme?*

Overall, all respondents would recommend this Computational Making Programme to other students, with 75% strong recommendation. All respondents enjoyed participating in the training sessions in the programme, with 67.9% strong agreement. 85.7% have started learning more about their own coding-related interests after attending the programme. Moreover, 85.7% want to do coding-related work in the future. 71.5% want to do design-related work in the future (such as design of products, apps, human-computer interfaces, etc)

Table 1

Pearson correlation analysis

	Recommendation	Enjoyment	Interest Development	Science & Math Readiness	Design Thinking Readiness	Problem Solving Readiness	Communication & Collaboration Readiness	Coding Readines
Recommendation	1							
Enjoyment	.718**	1						
Interest Development	.776**	.749**	1					
Science & Math Readiness	.341	.396*	.475*	1				
Design Thinking Readiness	.676**	.621*	771**	.286	1			
Problem Solving Readiness	.640**	.590**	.652**	.266	.764**	1		
Communication & Collaboration Readiness	.625**	.686**	.608**	.368	.595**	.855**	1	
Coding Readiness	.442*	.465*	.670**	.606**	.479**	.582**	.579**	1

***. Correlation is a significant at the .01 level (2-tailed, p < .01)*

**. Correlation is a significant at the .05 level (2-tailed, p < .05)*

5. Discussions

In qualitative feedback, one student responded: “Personally, it has helped me to improve my coding skills , and allowed me to now be able to code better, and find bugs more quickly e.t.c. This helps in finding errors in everyday life, and being more meticulous and careful in what I do, while teaching values such as perseverance and resilience as you feel the satisfaction after solving a bug”. Another student felt in another way: “It helped me gain more confidence in presenting things to other people and helped me cultivate more responsibility for my own projects and actions. In terms of academics, it has helped me think of solutions more effectively using methods like design thinking.” Some highlight agree that “I have improved in my math and computing classes, more others think “It has really inspired me to explore more into the field of mobile app development.”

The Pearson correlation analysis of the eight constructs of students’ perceptions of the Computational Making Programme and found they are highly correlated. With an SEM path analysis, it is found that design thinking Readiness and Coding Readiness as the two most common acknowledged factors in the programme for students to develop their interest and make recommendations to others. An ANOVA test shows that both boys and girls share similar perceptions and views on the programme.

6. Conclusion

As the literature suggested, a key strategy of that an effective learning environment of learning computational thinking through computational making would be one that is contextualised and most relatable to the students. This study, with K12 students learning in an out-of-school Computational Making Programme in Singapore, enables us to better understand students’ acceptances and perceived interdisciplinary readiness on six dimensions: on all the six dimensions: interest development, coding, design-thinking, math & science, problem solving, communication & collaboration. The quantitative data analysis indicated that most of the participating students, whether male or female, seem to have developed a high level of interest and acceptance of computational making activities. The correlational and SEM analysis indicated that although these students, from various schools, have benefited in different dimensions. Design thinking readiness and coding readiness should be highlighted as the prominent factors derived from this Computational Making Programme for students to develop their interest and make recommendations to others.

References

Álvarez, A., & Larrañaga, M. (2016). Experiences incorporating lego mindstorms robots in the basic programming syllabus: lessons learned. *Journal of Intelligent & Robotic Systems*, *81*(1), 117-129.

Barker, L. J., McDowell, C., & Kalahar, K. (2009). Exploring factors that influence computer science introductory course students to persist in the major. In *The Proceedings of the 40th ACM Technical Symposium on Computer Science Education - SIGCSE'09.* (pp. 153–157) doi:10.1145/1508865.1508923

Benda, K., Bruckman, A., & Guzdial, M. (2012). When life and learning do not fit: Challenges of workload and communication in introductory computer science online. *ACM Transactions on Computing Education (TOCE)*, *12*(4), 15.

Bennedsen, J., Caspersen, M. E., & Kölling, M. (Eds.). (2008). *Reflections on the Teaching of Programming: Methods and Implementations* (Vol. 4821). Springer.

Boy, G. A. (2013, August). From STEM to STEAM: toward a human-centred education, creativity & learning thinking. In *Proceedings of the 31st European conference on cognitive ergonomics* (p. 3). ACM.

Buechley, L., Eisenberg, M., Catchen, J., & Crockett, A. (2008, April). The LilyPad Arduino: using computational textiles to investigate engagement, aesthetics, and diversity in computer science education. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 423-432). ACM.

Buechley, L., Rosner, D. K., Paulos, E., & Williams, A. (2009, April). DIY for CHI: methods, communities, and values of reuse and customization. In *CHI'09 Extended Abstracts on Human Factors in Computing Systems* (pp. 4823-4826). ACM.

Gershenfeld, N. (2007). *Fab: The coming revolution on your desktop– from personal computers to personal fabrication.* New York: Basic Books, Inc..

Grove, F., Jorgenson, N., Brummel, B., Sen, S., & Gamble, R. (2011). Adapting rewards to encourage creativity. In *Multi-Agent Systems for Education and Interactive Entertainment: Design, Use and Experience* (pp. 51-69). IGI Global.

Hughes, R. M., Nzekwe, B., & Molyneaux, K. J. (2013). The Single Sex Debate for Girls in Science: a Comparison Between Two Informal Science Programs on Middle School Students' STEM Identity Formation. *Res Sci Educ, 43*(5), 1979–2007. doi:10.1007/s11165-012-9345-7

Jonassen, D., Howland, J., Marra, R.M., & Crismond, D. (2008). *Meaningful learning with technology* (3rd ed.): Pearson/Merrill Prentice Hall.

Kafai, Y. B. (2016). From computational thinking to computational participation in K--12 education. *Communications of the ACM*, *59*(8), 26-27.

Kafai, Y. B., & Burke, Q. (2014). *Connected code: Why children need to learn programming*. Mit Press.

Kafai, Y. B., Fields, D. A., & Searle, K. A. (2014a). Electronic textiles as disruptive designs: Supporting and challenging maker activities in schools. *Harvard Educational Review, 84*(4), 532–556.

Kafai, Y. B., Lee, E., Searle, K., Fields, D., Kaplan, E., & Lui, D. (2014b). A crafts-oriented approach to computing in high school: Introducing computational concepts, practices, and perspectives with electronic textiles. *ACM Transactions on Computing Education (TOCE)*, *14*(1), 1.

Kafai, Y., & Resnick, M. (1996). *Constructionism in practice: Designing, thinking, and learning in a digital world*. In Lawrence Erlbaum

Kim, A. S., & Ko, A. J. (2017) A pedagogical analysis of online coding tutorials. In *The proceedings of the 2017 ACM SIGCSE technical symposium on computer science education* (pp. 321– 326). ACM.

Kong, S.-C., Chiu, M. M., & Lai, M. (2018). A study of primary school students' interest, collaboration attitude, and programming empowerment in computational thinking education. *Computers & Education, 127,* 178–189. doi:10.1016/j.compedu.2018.08.026

Lewis, T., Creativity in technology education: Providing children with glimpses of their inventive potential. *International Journal of Technology and Design Education, 2009. 19*(3): p. 255-268.

Lim, B., Hosack, B., & Vogt, P. (2012). A Framework for Measuring Student Learning Gains and Engagement in an Introductory Computing Course: A Preliminary Report of Findings. *Electronic Journal of e-Learning, 10*(4), 428-440.

Lye, & Koh. (2014). Review on teaching and learning of computational thinking through programming: What is next for K-12? *Computers in Human Behavior, 41*, 51–61.

Marenko, B. (2015). When making becomes divination: Uncertainty and contingency in computational glitch-events. *Design Studies, 41, 110–125.*

Marshall, P., Cheng, P. C. H., & Luckin, R. (2010, January). Tangibles in the balance: a discovery learning task with physical or graphical materials. In *Proceedings of the fourth international conference on Tangible, embedded, and embodied interaction* (pp. 153-160). ACM.

Mellis, D., Follmer, S., Hartmann, B., Buechley, L., & Gross, M. D. (2013, April). FAB at CHI: digital fabrication tools, design, and community. In *CHI'13 Extended Abstracts on Human Factors in Computing Systems* (pp. 3307-3310). ACM.

Papert, S. (1986*). Constructionism: A new opportunity for elementary science education*. Massachusetts Institute of Technology, Media Laboratory, Epistemology and Learning Group.

Peppler, K., D. Glosson, Y. Kafai, D. Fields, and K. Searle. Articulating creativity in a new domain: expert insights from the field of e-textiles. in Proceedings of the 8th ACM conference on Creativity and cognition. 2011. ACM.

Pierce, R., Stacey, K., & Barkatsas, A. (2007). A scale for monitoring students attitudes to learning mathematics with technology. *Computers & Education, 48*, 285–300. doi:10.1016/j.compedu.2005.01.006

Renumol, V., Jayaprakash, S., & Janakiram, D. (2009). Classification of cognitive difficulties of students to learn computer programming. *Indian Institute of Technology, India*, 12.

Riddle, S. (2015). The robots are coming for your job! Why digital literacy is so important for the jobs of the future. *The Conversation*, *27*, 1-4.

Rode, J. A., Weibert, A., Marshall, A., Aal, K., von Rekowski, T., El Mimouni, H., & Booker, J. (2015). From computational thinking to computational making. *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing - UbiComp '15.* doi:10.1145/2750858.2804261

Rosner, D. K. (2010, April). Mediated crafts: digital practices around creative handwork. In *CHI'10 Extended Abstracts on Human Factors in Computing Systems* (pp. 2955-2958). ACM.

Stevenson, M., Falloon, G., Forbes, A., & Hatzigianni, M. (2018). High Impact Learning and Teaching using 3D Design and 3D Printing in Primary School Makerspaces. *ACCE 2018*, 75.

Tanenbaum, J.G., A.M. Williams, A. Desjardins, and K. Tanenbaum. Democratizing technology: pleasure, utility and expressiveness in DIY and maker practice. in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems 2013*. ACM

Tenenberg, J. (2018). Computational making. *Computing Education Research*, *9*(1), 22-23.

Xie, L., A.N. Antle, and N. Motamedi. Are tangibles more fun?: comparing children's enjoyment and engagement using physical, graphical and tangible user interfaces. in Proceedings of the 2nd international conference on Tangible and embedded interaction. 2008. ACM.