Making Activities for the Competency Development of School-Age Children

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Abstract—***Contributions:*** **This study examined the effectiveness of making activities in fostering the competency development of school-age children engaged in a making program. The findings suggest that community-based makerspaces can provide autonomous and informal learning experiences, facilitating their competence development. When integrated with formal learning in schools, these experiences can facilitate a well-rounded education that nurtures 21st century skills in the younger generation.**

Background: **The making program, hosted by community youth centers in Hong Kong, comprised a series of five workshops. These workshops provided guidance throughout the creative processes, encouraging participants to invent artefacts under the theme of "smart design for living."**

Research Questions: **What generic skills and other attributes can school-age children develop through making activities? What factors influence their development of generic skills and other attributes? What disparities emerged between their community-based and school-based making experiences?**

Methodology: **The study utilized a mixed-method approach, encompassing of a pre- and post-test questionnaire survey involving school-age children who took part in the making workshops ($N = 232$), as well as semi-structured interviews with a subset of the participants ($n = 25$).**

Findings: **Survey results revealed significant enhancements in participants' information technology skills, communication skills and divergent thinking, along with a favorable acceptance of the making tools. Pertinent topics related to competency development, including age-related effects, computer accessibility, and mobile device ownership, were examined and discussed within the context of the study.**

***Index Terms*—Children, coding, education, makerspace, making.**

I. Introduction

MAKING is a cultural trend that focuses on an individual's ability to be a creator of things [1]. Based around the premises of "to build," "to explore," and "to program" with materials in a contingent and interactive fashion [2], making has recently received greater attention because of the advancement of mobile technology and minimal computing, both of which have allowed the current generation to access affordable computational devices and empower them to turn ideas into products through design, invention, and building. Because of its associated learning opportunities for children and teenagers [3], a number of makerspaces and making programs, aimed at developing students' interest and abilities in both formal and informal school settings, have emerged.

Previous studies have revealed the advantages of making for students' learning, both within and beyond the school setting [4], [5]. This is particularly evident in how the act of making contributes to the acquisition of knowledge and skills in core subject, such as science, mathematics, and languages [6], [7], [8]. Additionally, there has been growing interest in the development of more generic competencies, including the critical thinking, creativity, communication, and collaboration (4C) [9]. However, the competency development in school-age children through making activities outside the school environment remains relatively unexplored. Bevan et al. [10] suggested that gaining a deeper understanding of how learning occur in nontraditional educational contexts is crucial. This understanding can help clarify what constitutes learning and provide a rationale for integrating making activities into formal education. In response to the increasing prevalence of making activities and their potential to enhance the preparedness of the younger generation for future challenges, this study was conducted within the context of community youth centers to examine the effectiveness of making activities and their impact on the competency development of school-age children, with a particular focus on the cultivation of generic skills and other attributes associated with 21st century skills [11]. The following research questions guided this study.

1) What generic skills and other attributes can school-age children develop through making activities?
2) What factors influenced their development of generic skills and other attributes?
3) What disparities emerged between their community-based and school-based making experiences?

A. Making and Learning

Participating in making activities enables children to engage in experiential learning while they play and build with interesting tools and materials. In addition to broadening their horizons and equipping them to navigate a technology-rich

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future [12], making offers hands-on opportunities for experiential learning, allowing individuals to connect their interests with the world around them. It fosters an environment where learners can share ideas and showcase their creations, while failure is celebrated as a positive aspect of progress [13]. What sets making apart from other learning activities is its democratic nature, permitting anyone to become a creator [14], take ownership of their learning, and build confidence in their ability to acquire new knowledge and skills [15]. Moreover, embedded within the design of making itself, which is inherently stimulating [16], learning becomes a dynamic and ongoing journey, rather than a fixed entity to be evaluated. Engaging in making activities enables children to discover more about themselves and their surroundings in an enjoyable, immersive and meaningful manner.

Learning through making activities offers a distinctive approach that effectively addresses the current educational needs of school-age children in several ways.

1) The making process places a strong emphasis on learning with technology, which fosters the development of essential 21st century competencies, including computational thinking and information literacy skills [11].
2) Making is closely intertwined with STEM concepts [17], [18], aligning with the interdisciplinary trend in school education.
3) Making adopts a learning-by-demand model, ensuring that learning is contextually relevant and meaningful, as opposed to the traditional just-in-case model, which covers a predetermined curriculum in the hope of future utility [19].
4) Making culture advocates a growth mindset that empowers makers with autonomy and control, fostering engagement and persistence in their endeavors. It motivates makers by involving them in hand-on tasks which are both challenging and interesting [20]. A potential outcome of such endeavors is the development of self-directed learners, a competence that is especially important in the modern world.

Previous studies have examined factors contributing to the effectiveness of learning through making. Giannakos and Jaccheri argued that students' attitude and motivation to learn are influenced by their acceptance of technology [21]. This perspective is partially supported by Nikou et al., whose studies revealed positive feedback from primary school students regarding the perceived ease of use and usefulness alongside their engagement with making and digital design [22], [23]. Gender stereotypes have been an issue in making movement, as Eckhardt et al. [24] found that there were more male than female makers. This disparity may be attributed to the perception that making and crafting are closely associated with engineering, a field predominantly occupied by males. Holbert raised the issue of making being embraced by highly educated and affluent white men, advocating for more diverse and inclusive practices to encourage engagement from underrepresented and underserved communities [25]. Bekker et al. [26] identified the importance of matching learning goals, interests, age, activities, and relevance with the tools provided to makers.

B. Making Outside Schools

The majority of scholarly work on learning through making has primarily focused on the schooling context, specifically on the school library makerspace [27] and the integration of making in the classroom for subject matters related to programming and STEM [17], [28]. Scholarly efforts have also been made to explore and compare the making experiences of school-age children with those that occur after school or in a community context. Based on their interviews with practitioners, Einarsson and Hertzum found that one of the main challenges faced by users of community-based makerspaces, such as public libraries, is the perception held by insiders that communities pose a barrier to newcomers [29]. Another challenge is the lack of sustainability when it comes to scaffolding community-driven activities for meaningful making and learning experiences. Shan and Wang investigated online making communities as new environments for makers to collaborate with one another [30]. Results from social network analysis have shown that social presence plays a significant role within makers' communities, while issues related to information security and privacy within online spaces are major concerns among interviewees. The element of community building appears to influence whether makers continue to use a makerspace, the sense of ownership they develop over the space and their projects, their determination in overcoming setbacks, and the outcomes of their participation in the space [27].

The existing literature has highlighted the distinctions between making within formal and informal learning contexts. Sefton-Green pointed out that making activities within schools often tend to be more guided, aligning with formal learning practices, as opposed to makerspaces outside of school environments [31]. Halverson and Sheridan suggested that making in schools places a greater emphasis on the final product and associated processes, as opposed to the tools used [3]. This stands in contrast to the approach prevalent in informal learning, which encourages exploration, tinkering, discovery, and the development of understanding in conjunction with others, the tools, and materials provided [32]. Bowler and Champagne conducted focus group and semi-structured interviews with young makers from library, youth center, museum, and nonprofit organization makerspaces [33]. The qualitative findings revealed characteristics of informal learning in community makerspaces, which contrasted with the structured and formal learning found in schools. They also found that participation in making within informal learning spaces was driven by personal interests, rather than being an obligatory aspect as in school settings. Scaffolds for learning within such informal learning environments emerge organically and may not always conform to the structure of a formal lesson plan or a structured activity. Wallingford et al. [34] explored young makers' self-directed making activities within a community setting. They found that the informal context allows them to scope the problem, define their own goals, overcome the challenges and pursue their own goals in an autonomous manner. This is echoed by Brown and Antink-Meyer, who found that making in informal settings can facilitate sharing of knowledge through collaboration [35]. Adopting a biblio-narrativical approach, Tan et al. [36] revealed the importance of a positive socio-cultural environment in interest development and sustainability of an informal makerspace.

C. Making and Competency Development

Generic skills, sometimes also referred to as transferable skills or 21st century skills [37], are crucial for children's personal growth and their preparedness for the workforce, which demands flexibility, initiative, and the ability to solve diverse tasks. While definitions may vary [38], the existing literature uses these terms to encompass a broad range of fundamental abilities and competencies that can be applied across different situations and contexts. These skills often include recurring themes, such as collaborative skills, communication skills, information technology (IT) skills, and problem-solving skills. Other related attributes include, but are not limited to, self-management skills, study skills, decision-making skills and systematic reasoning, along with design and divergent thinking.

Weng et al. [9] conducted a case study to examine the 4C development of school-age children through problem-based digital making tasks. Their findings, which indicated that these tasks could scaffold the development of communication and collaborative skills, was further supported by Ng et al., whose study focused on computational and problem-solving skills, along with dispositions, during digital making activities [39]. In another case study, Kim and Ruters discovered that systematic reasoning could be fostered through competency-based making curriculum design [40]. Through observations of video screen recordings of children's making processes involving tablets and 3-D printing technologies, Hatzigianni et al. [41] revealed a range of manifestations, including design, creative and critical thinking, problem-solving, and decision-making skills. This suggests that children's engagement in making activities can offer rich learning opportunities. Exploratory and observational studies conducted by Smith et al. [42] indicated that making in primary and secondary school settings can benefit from design thinking and provide students with a general understanding of the creative and complex process of digital fabrication, particularly when integrated into the educational setup. Koul et al. [43] argued that the generation of ideas in the making process can encourage makers to think outside the box, fostering divergent and creative thinking in an experimental and collaborative manner. The case study by Vuopala et al. [44] revealed the development of students' study skills through the making process, a competency that can enhance learn efficiency and information retention over time. Participating in making activities also had the potential to improve one's ability to manage and organize time, resources, and behavior. This was one of the outcomes of a case study conducted by Berg et al. regarding the development of makers' self-management skills [45].

Tyrén et al. [46] conducted secondary research by gathering data from participating teachers and students to identify considerations involved in the design and planning of making activities. Their findings led to the introduction of computational thinking into the primary school curriculum. Similarly, Korhonen et al. [47] surveyed students' development of 21st century competencies after their participation in school-based making activities. In their study, decision-making, collaborative and problem-solving skills—all of which can be cultivated through making—were rated as crucial. It is worth noting that both studies utilized the BBC *micro:bit* as the platform for their making activities, which is the same platform used in the current study.

II. Methodology

To examine the effectiveness of making activities in fostering the competency development of school-age children, this study employed a quasi-experimental design to assess participants' development of generic skills and other related attributes within a making curriculum implemented in community youth centers. It adopted a mixed-method approach that encompassed both a pre- and post-test questionnaire survey with 232 school-age children enrolled in the making program and semi-structured interviews with 25 of these participants upon program completion. This approach facilitated data triangulation, thereby bolstering the validity of the findings [48].

A. Making Curriculum Design and Implementation

A community-based making curriculum based on the theme smart design for living was developed and implemented for this study. The theme aligned with the Smart City Blueprint of the local government "with the vision to embrace innovation and technology to build a world-famed smart Hong Kong characterized by a strong economy and high quality of living" [49], while the curriculum—designed and implemented by the Hong Kong Federation of Youth Groups, a nonprofit and the largest youth service organization in Hong Kong—aimed to develop participants' knowledge and skills for making, in doing so fostering their generic skills development. The researchers in this study served as consultants for the curriculum design, providing advice with regard to curriculum alignment, offering guidance on the relevance of the making activities for competency development, and conducting the evaluation of the curriculum implementation. They identified a list of generic skills and other attributes associated with making. These generic skills were drawn from the official school curriculum document published by the Education Bureau [50]. Of the initial nine generic skills listed in the document, three were omitted following discussions among the researchers and curriculum designers from the collaborating organization, as they were deemed irrelevant to making. Alongside the remaining six items (collaborative skills, communication skills, IT skills, problem-solving skills, self-management skills, and study skills), the researcher also identified five other attributes pertinent to makers' learning experiences from the literature. These attributes include decision-making, learning motivation, systematic reasoning, design and divergent thinking [40], [41], [42], [43], [51].

The making curriculum comprised five 90-min making workshops, each dedicated to a specific topic with relevant teaching content and learning activities leading to the creation

TABLE I
TOPIC, TEACHING CONTENT, AND LEARNING ACTIVITIES OF THE MAKING CURRICULUM

Workshop	Topic	Teaching Content	Learning Activities
1	Automatic device	- Basic *micro:bit* operations - Basic programming skills - Connecting devices	- Testing with in-built buttons, light sensor and LED monitor - Traffic light design
2	Personal smart device	- Using in-built sensors - Mathematical functions - Design process	- Design of name tag, stop watch, compass and alarm - Discussion on smart design for living
3	Robot car	- Programming for motors - Vehicle engineering - Programming automatic vehicle	- Design of automatic vehicle with obstacle avoidance
4	Smart city design	- Using peripheral sensor - Input and output coordination - Smart city inventions	- Design of security system and prototyping of smart parking
5	Challenge your creativity!	- Networking and logistics - Revision and round-up	- Design of weather station - Smart device creation

of at least one smart design artefact by the participants (see Table I). These artefacts are everyday technologies with which children are familiar with and can be easily replicated within the scope of a making workshop. Engaging in these planned learning activities enables children to develop the aforesaid generic skills and other attributes in an enjoyable and subconscious manner. For example, they may develop communication and collaborative skills through interactions with peers in group work, or nurture divergent thinking and systematic reasoning when exploring various approaches to problem-solving during the fabrication process. Furthermore, by engaging with the making tools and coding environment in an engaging and stimulating manner, they may begin to recognize the usefulness of these technologies and find it easier to work with them [51]. This, in turn, can contribute to their acceptance of technology, which potentially enhance their competence development. A total of 25 classes with different groups of children were implemented concurrently on a weekly basis for the five workshops in six community centers by making instructors trained by the organization. The *micro:bit*, an open source hardware system designed by the BBC for computer education, was used as the design platform in the making activities. Widely used in making education, the platform has been found to be effective with school-age children [46], [47], [52], [53].

B. Participants and Procedure

The participants ($N = 232$) were school-age children who enrolled in the aforementioned making program; 65.47% of the participants were boys and 34.53% were girls. Nearly half of the participants (47.79%) were aged 8 to 9 years old, which corresponds to primary three and four in the Hong Kong education system. In terms of ownership and access to technology, 51.98% of the participants responded that they usually use computers in school, with 66.52% using them at home; 57.83% of them owned a smartphone, while 52.65% of them had a tablet at home that they could access. Most of them (83.19%) had coding experience with the making platforms identified by the researchers, including *App Inventor*, *Arduino*, *Kodu*, *Scratch*, *micro:bit*, *mBot*, and *Minecraft*. Table II shows the demographic information of the participants based on an overall average attendance rate of 87.41%.

TABLE II
DEMOGRAPHIC INFORMATION OF THE PARTICIPANTS

	Number of Participants
Gender	
Boys	65.47%
Girls	34.53%
Age range	
7 or below	1.77%
8 to 9	47.79%
10 to 11	30.53%
12 to 13	15.04%
14 or above	4.87%
Usual access to computers	
In school	51.98%
At home	66.52%
Ownership of mobile devices	
Possess a smartphone	57.83%
Access to tablet at home	52.65%
Coding experience with making platforms	
Formal lessons at school	49.13%
Extra-curricular activities at school	18.97%
Outside school	42.67%
No experience	16.81%

Parental consent was sought on behalf of the children concerned at the time of enrolment to participate both in the study and the making program. Parents were provided with an information sheet that briefed them on the details of the study; in addition to being verbally briefed at the beginning of the first lesson and receiving an informal invitation to join the study, the assent form for children was given to the participants via their parents. Once agreement had been reached, the pretest questionnaire was distributed to the children to fill in before undertaking the making activities. The post-test questionnaire survey was conducted immediately after the final workshop, both questionnaires taking around 5 to 10 min to complete. The class tutor then asked for a volunteer who was willing to be interviewed by one of the researchers. The semi-structured interviews, which lasted around 15 min, were conducted in the same room after everyone else had left. The interviews were voice-recorded and transcribed by the research team for further analysis. The participants were assured that their

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responses would be treated as confidential and anonymous. Ethical clearance was obtained beforehand from the human research ethics committee at the same university where the authors were based.

C. Questionnaire Survey and Semi-Structured Interviews

Both the pre- and post-test questionnaire survey consisted of two parts. The first part of the pretest collected demographic information, including the participants' age range, gender, computer, and tablet access, smartphone ownership, and their coding experience. The second part collected their self-assessed achievements in generic skills and other attributes related to making as discussed above. Taking into consideration the comprehension skills of the participants in relation to the understandability of the generic skills, the items were then formulated and restructured as simple questions that could be understood and rated easily by school-age children on a 5-point Likert scale. For example, their collaborative skills were assessed by their rating of the question "Are you able to collaborate with others in teamwork?"

In additional to the self-assessed achievements in generic skills and other attributes related to making, the post-test questionnaire also included items that assessed participants' levels of technological acceptance as part of the curriculum evaluation. The collection of data on participants' technology acceptance of making was considered crucial due to its significant impact on the success of children's learning-by-making experience [21]. These items were designed by the researchers based on the technology acceptance model (TAM) [54] and took into account the contextual considerations of the making curriculum, and were rated on a 5-point Likert scale.

The interview questions were used to contextually supplement the survey results. The design of the open-ended questions aligned with the principles of content, clarity and sequencing [55] and referenced the constructs of the questionnaire's generic skills and TAM. The questions covered participants' perceptions regarding the development of their generic skills and other attributes, together with their learning experiences as participants in the making workshops. The interviews were guided by the following series of questions.

1) Why did you participate in this making program?
2) What difficulties did you encounter in the making process?
3) How did you solve the problems you encountered?
4) Apart from the examples provided by the tutor, what sources inspired your ideas for the living design that you made in the final workshop?
5) How did this making experience differ from that of related activities in school, such as ICT and STEM lessons?
6) What do you like making the most in the youth center?

Prior to the implementation of the making curriculum, a focus group pilot study was conducted with a group of ten primary school students aged 8 to 9. Based on their feedback, evaluations and improvements to the understandability of the survey instruments were carried out.

D. Analysis, Internal Reliability, Normality, and Homogeneity of Data

The study employed SPSS to analyze the reliability, means, standard deviation, and significance of the quantitative data obtained from the questionnaire survey. Cronbach's alpha was used to estimate the reliability of the quantitative data from the questionnaire survey, which contained multiple items measuring the generic skills and technology acceptance levels of the participants; the alpha coefficients were rated as "excellent" for TAM (α =0.93) and "good" for both the pretest (α =0.82) and post-test (α =0.86) for the generic skills [56]. The Kolmogorov–Smirnov test and Levene's test were conducted in order to assess assumptions of normality and homogeneity of variance—no violations were found in either test. The intercoder reliability of the interview data coded independently by research team members was calculated using Krippendorff's alpha, which was favorably calculated at 0.912 [57]. The qualitative data were thematically analyzed, building upon the findings from the quantitative analysis. This process involved the researchers reading through each line, sentence and paragraph of the interview transcripts to provide contextual elaboration on how participants develop generic skills and other attributes during their engagement in making activities, as well as how external factors may have affected their competence development.

III. Findings

A. Technology Acceptance With Making

Table III summarizes participants' self-assessed rating scores of TAM items for their making experience as collected in the post-test survey. Rated on a 5-point Likert scale from "strongly disagree" to "strongly agree," the overall mean score of 3.85 indicates a good technology acceptance of making. One-way analysis of variance (ANOVA) was conducted in order to determine if the rating scores of TAM items were different across the independent variables in Table II. With the exception of age, no significant differences were found across gender, access to and ownership of technology. Results yielded significant differences in Item 2 ($F[4, 210] = 3.115$, $p < 0.05$) and Item 3 ($F[4, 210] = 3.115$, $p < 0.05$) between different age groups, with older age groups rating higher than younger age groups.

B. Generic Skills Development

Table IV shows the results of the paired sample t-tests that were conducted in order to compare the rating scores of pre- and post-test generic skills items. Descriptive analysis revealed higher-post-test scores for all the generic skills items; significant differences were also found between pre- and post-test results within the domains of communication ($t(217) = 2.06$, $p < 0.05$) and IT skills ($t(215) = 2.85$, $p < 0.05$), but not in collaborative ($t(214) = 0.55$, $p > 0.05$), problem-solving ($t(211) = 1.74$, $p > 0.05$), self-management ($t(212) = 0.69$, $p > 0.05$), and study skills ($t(216) = 1.54$, $p > 0.05$).

Although many participants reflected that coding constituted the most difficult element of a making activity, successful

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TABLE III
MEAN SCORES OF PARTICIPANTS' SELF-ASSESSED TECHNOLOGY ACCEPTANCE OF MAKING

Age Group:	**<7 (n=10)**	**8-9 (n=102)**	**10-11 (n=67)**	**12-13 (n=32)**	**>=14 (n=3)**	***M (SD)***
1. Learning *micro:bit* can help me understand design	3.40	3.79	4.10	4.09	3.00	3.89 (1.11)
2. Learning *micro:bit* can enhance my ability to analyze problems*	3.40	3.63	4.10	4.03	2.67	3.81 (1.16)
3. Learning *micro:bit* can enhance my ability to think from different perspectives*	3.60	3.86	4.13	4.16	2.67	3.95 (1.05)
4. Learning *micro:bit* is easy	3.50	3.70	4.03	3.72	3.33	3.78 (1.19)
5. Learning *micro:bit* is more interesting than other subjects	3.40	3.77	4.15	3.97	3.00	3.88 (1.14)
6. Learning *micro:bit* can open up more common topics between classmates and friends	3.33	3.71	4.00	3.87	2.33	3.78 (1.17)
7. I will continue to learn other coding / programming	3.20	3.82	4.15	3.94	3.00	3.90 (1.16)
8. I will continue to explore more about coding / programming	3.20	3.68	4.12	3.81	3.00	3.79 (1.26)
Average:	3.39 (1.39)	3.74 (0.95)	4.10 (0.78)	3.95 (0.96)	2.88 (0.33)	3.85 (1.15)

Note. *Significant differences between age and these technology acceptance items

TABLE IV
MEAN SCORES AND PRE- AND POST-TEST DIFFERENCES OF PARTICIPANTS' GENERIC SKILLS ITEMS

	Pre-test		**Post-test**					
	M	***SD***	***M***	***SD***	**Difference**	***t*-value**	**d*f***	***p*-value**
Collaborative skills	3.84	1.07	3.88	1.07	.047	0.55	214	.587
Communication skills	3.74	1.09	3.92	1.08	.174	2.06	217	.041*
IT skills	3.39	1.29	3.68	1.18	.287	2.85	215	.005*
Problem-solving skills	3.61	1.04	3.76	0.99	.151	1.74	211	.084
Self-management skills	3.79	1.03	3.85	1.03	.056	0.69	212	.493
Study skills	3.69	1.09	3.83	1.15	.138	1.54	216	.125

achievements within this area enabled them to solve a number of other technical problems. For example, they learned how to use the building blocks in *Scratch*, the visual programming platform compatible with *micro:bit*, to write specific programs for particular tasks. Some of them were even able to understand coding concepts and used specific terms to explain their learning process.

> Building blocks were difficult. The instructions that were provided didn't seem to be very accurate, so I needed to find out where it had gone wrong and make corrections. (Student B)

> It is difficult to find the correct API (application programming interface) to control the speed of the car. (Student F)

> Different LED colors can be used to model the traffic light. (Student D)

Participants demonstrated the use of communication skills within teamwork and individual problem-solving. For example, they asked for help from group members and their tutor in order to sort out the technical issues they encountered.

> I asked my neighboring groupmate first, or the tutor if things still didn't work. (Student C)

> I would consult the tutor and solve the problem with his help. (Student G)

In addition to asking for help, participants responded that they could also attempt to study and solve problems on their own. The methods they used included trial and error, working backwards, and means-ends analysis.

> I tried to disconnect and reconnect all the cables to see if I had missed anything. (Student H)

> Quite a lot of time was needed to build the robot car, and there were some errors during the process. I needed to undo the steps one by one in order to find out the error. (Student I)

> I would ask the teacher if there were any references that could be provided. (Student J)

C. Development of Other Attributes

Table V shows the results of a paired sample (t-test comparing the pre- and post-test rating scores of other attributes. Similar to generic skills development, the increasing scores indicate an improvement in these attributes. Paired items were found to be significantly different for divergent thinking ($t(216) = 1.99$, $p < 0.05$), but not for decision making ($t(215) = 0.86$, $p > 0.05$), learning motivation ($t(218) = 1.72$, $p > 0.05$), systematic reasoning ($t(213) = 0.83$, $p > 0.05$), or design thinking ($t(215) = 1.48$, $p > 0.05$).

When asked about the sources of design ideas, participants responded that they drew inspiration from daily life.

> My idea came from the *LEGO* building blocks that I used to play with. (Student A)

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TABLE V
MEAN SCORES AND PRE- AND POST-TEST DIFFERENCES OF PARTICIPANTS' OTHER ATTRIBUTES

	Pre-test		Post-test					
	M	*SD*	*M*	*SD*	Difference	*t*-value	df	*p*-value
Decision making	3.72	0.99	3.78	1.03	.065	0.86	215	.388
Learning motivation	3.89	0.99	4.03	0.97	.137	1.72	218	.087
Systematic reasoning	3.60	1.05	3.67	1.05	.070	0.83	213	.405
Design thinking	3..48	1.11	3.62	1.09	.139	1.48	215	.140
Divergent thinking	3.64	1.07	3.80	0.98	.166	1.99	216	.048*

> I referenced the compass and pedometer that I used during the picnic, then tried to make the same thing during the lesson. (Student E)
>
> I made the design based on what I needed. (Student K)

Although not necessarily significant in their own right, participants' responses reflected the contributions of other attributes to the development process. For example, they explained how they made decisions based on systematic reasoning in order to solve problems.

> After I had figured out where the error was, I rewrote and double-checked the relevant codes with the instructions provided. (Student N)
>
> The computer program couldn't be uploaded from the notebook to *micro:bit*, so I guessed that the USB cable was malfunctioning. (Student P)

They also mentioned the stimulating effects of making that motivated them to learn related subject matters, both inside and outside school.

> I like to build robots, and so I want to know more about coding. (Student Q)
>
> I have learnt *micro:bit* in my school before, and I wanted to know more about it here in the making program. (Student L)
>
> I know that my school will teach something related to this course in the future, so I want to start preparing now. (Student O)

D. Factors Affecting Generic Skills and Other Attributes

Repeated measures ANOVA was conducted to determine if the participants' demographic factors in Table II and their technology acceptance had any effect on the increased rating scores of communication skills, IT skills and divergent thinking, all of which were found to be significantly different. The technology acceptance rating scores were calculated by averaging the TAM items in Table III. The effects of age ($F = 3.99$, $p < 0.05$), usual access to computers ($F = 2.71$, $p < 0.05$), ownership of mobile devices ($F = 5.22$, $p < 0.05$), and technology acceptance ($F = 15.04$, $p < 0.05$) were all found to be statistically significant on participants' IT skills, indicating that they were correlated. However, while technology acceptance also had a significant effect on communication skills ($F = 6.01$, $p < 0.05$) and divergent thinking ($F = 13.24$, $p < 0.05$), no significant effects were found between these factors and collaborative skills or divergent thinking. Similarly, the effects of age were found to be insignificant. Table VI shows the results of the statistical analysis.

TABLE VI
CORRELATIONS BETWEEN PARTICIPANTS' DEMOGRAPHIC FACTORS AND THE INCREASE IN COMMUNICATION SKILLS, IT SKILLS, AND DIVERGENT THINKING

	Gender	Age	Usual Access to Computers	Ownership of Mobile Devices	Technology Acceptance
Communication Skills					
F	0.02	2.24	0.45	0.77	6.01
p-value	.900	.069	.841	.513	.016*
IT Skills					
F	3.68	3.99	2.71	5.22	15.04
p-value	.058	.005*	.017*	.002*	.000*
Divergent thinking					
F	2.95	1.49	2.02	1.92	13.24
p-value	.089	.210	.069	.130	.000*

Bivariate analysis was conducted in order to assess associations within the pairs of dependent and independent variables in Table V whose correlations were found to be significant. No significant association was found between IT skills and age ($n = 213$, $p = 0.311$), usual access to computers ($n = 215$, $p = 0.225$), ownership of mobile devices ($n = 213$, $p = 0.628$), and between communication skills and technology acceptance ($n = 218$, $p = 0.122$). However, positive significant associations were found between IT skills and technology acceptance ($r = 0.399$, $n = 216$, $p = 0.000$), and between divergent thinking and technology acceptance ($r = 0.248$, $n = 217$, $p = 0.000$).

Two simple linear regressions were conducted to predict participants' development in IT skills and divergent thinking in relation to their technology acceptance. Results showed that technology acceptance was a positive predictor of IT skills ($F(1, 214) = 40.533$, $R^2 = 0.159$, $R^2_{\text{adjusted}} = 0.155$, $p = 0.000$) and divergent thinking ($F(1, 214) = 13.991$, $R^2 = 0.061$, $R^2_{\text{adjusted}} = 0.057$, $p = 0.000$) development.

E. Community-Based Making Experience

Participants shared their making experience within the context of community youth centers. They mentioned that the informal learning experience was less structured and rigid when compared to similar learning activities in school.

> In school, I have to follow teachers' instructions when making something. We all (students) have the same standard kits, and aim to make the same thing. Here, we are free to add things to the existing product, once we have finished. (Participant R)
>
> We were told step by step how to make the car work in the classroom... It was similar here, but I have a

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> bit more independence and can take greater control of my own progress. (Participant T)

Participants reflected that they preferred making in the community youth centers to those related learning activities in schools for several reasons.

> I have more choice in terms of what I want to do. (Participant S)

> I am given more freedom to choose what I want to make in the making program. (Participant M)

> I can discuss with others and the tutor, which is normally not the case in school. (Participant U)

IV. Discussion

The current study examined the competency development of school-age children in a making program contextualized within community youth centers. In response to the research questions, the findings of this study revealed 1) significant development was found among participants' IT skills, communication skill, and divergent thinking; 2) age, usual access to computers, ownership of mobile devices and technology acceptance were significant contributing factors to participants' development of IT skills, while technology acceptance also had a significant effect on the development of communication skills and divergent thinking; and 3) more autonomy was captured within the community-based making activities as part of the participants' informal learning experiences, which contrast with making in schools making activities in schools were guided by teachers with standardized tools and procedures, a finding that addresses the dearth of scholarly works looking into school-age children's learning-through making experience beyond formal education.

Previous studies have uncovered the advancement of makers' development in IT skills, communication skills, and divergent thinking in out-of-school contexts [9], [39], [58]. The outcomes of this study furnish evidence that supporting their noteworthy enhancement with statistically significant results. Although participants concurred that coding was the most difficult part of the making process, they employed various strategies to address the technical problems. In doing so, they inadvertently nurtured their acquisition of the aforementioned competences. These strategies encompassed, among others, trial and error, retracing steps to identify malfunctioning components, and seeking assistance from peers and tutors. These strategies align with the approaches that makers have adopted in formal learning environments at school [9], [41], [42]. Furthermore, any frustration experienced during the making process may have been offset by the stimulating effects afforded by their engagement in the making activities. This engagement encouraged them to communicate and interact with the tutor and other students in a bid to seek solutions to their problems, even though they may have only met during the making workshops. Such making routines contributed to the learning opportunities leading to the development of makers' generic skills and other attributes.

Another interesting finding that this study yielded was the relationship between participants' self-assessed technology acceptance with the making tools and other dependent and independent variables. Although significant differences were found among participants in different age groups for the rating scores of only two TAM items, distributions of the individual and averaged TAM scores exhibited a bell-shaped curve across various age groups, indicating that the maker tools and curriculum designed for this study were better received by senior primary school-age participants than by older or younger students. Since catering to makers of different ages represents one of the main differences compared with making in schools, careful consideration to the design of making activities is needed in order to ensure that community-based makerspaces are ideal for participants of all ages [59]. The study also revealed that participants' technology acceptance was significantly correlated to their competency development, a finding that may not have been addressed in previous studies. The implication of this is that considerations of age may indirectly affect makers' choice of tools, a potentially important factor in terms of the design of making activities. This echoes the findings of Bekker et al., who identified the importance of matching learning goals, activities and their relevance with the tools provided to school-age makers [26].

IT skills, and the ability to use IT critically to search, select, analyze, manage and share information, is an important component of those 21st century skills that facilitate one's self-directed learning and problem-solving capacities [60]. While previous studies have explored the impact of children's age [61], mobile device ownership [62] and access to computers at home [63] on their IT skills in different situations, the significance of the results yielded from this study lie in their contribution to such correlations by placing them within the context of community youth centers. Apart from the age factor discussed above, there is also a need for community-based makerspaces to cater to those who may not own or have direct access to computers. This can be facilitated by providing free-to-access computational devices in the youth center itself, or alternatively the provision of loan schemes that allow makerspace members to borrow computers and / or other mobile devices. While no significant gender-related findings emerged, the demographic information revealed that the majority of the participants were boys. The dominance of males in making has been a persistent issue along with various stereotypes [24], [25], highlighting the necessity for increased efforts to promote the significance and value of making in order to engage more diversified communities.

During the interviews, participants highlighted the autonomous and informal learning opportunities afforded by the youth center makerspace as one of the main differences between community-based and school-based making. The participants experienced greater freedom to make choices during the making processes and were encouraged to derive ideas from their daily lives. As a result, their engagement in making transformed into a more individualized and self-directed learning experience, motivated by personal interest [33], [34]. This stands in contrast to formal learning in schools, where making participation is structured and directed to align with curriculum learning objectives [3]. The voluntary nature of participation, as if the children find it fun and enjoyable [64], enables learning to occur unconsciously during their leisure time. These differences arguably present an even starker contrast within the Hong Kong schooling context, where class sizes are unfavorably large in relation to catering to individual differences and engaging students in diversified activities [65], [66], [67], especially when coupled with the use of formal, high-stakes summative tests as the sole assessment method for students' learning outcomes [68]. In addition to the benefits afforded by the informal nature of out-of-school makerspaces in terms of learning opportunities that support makers' technical practice, creative production, knowledge sharing, collaboration, and self-directed learning [33], [34], [35], [69], community-based makerspaces, whether in Hong Kong or elsewhere, collectively represent alternative and stimulating learning experiences leading to the competency development of school-age children.

V. Limitations

Several limitations were identified that may provide valuable insights for further research. In this study, the curriculum was developed by a nonprofit youth service organization in Hong Kong, with input from researchers. Additionally, the making platform and teaching content were dedicatedly selected and tailor-made for school-age children in Hong Kong. These two factors could potentially impact the generalizability of the findings or offer insights into the making practices in regions with diverse cultures and educational systems. The questionnaire only assessed motivation as a single item in the pre- and post-tests. Since motivation encompasses a range of building blocks, as informed by self-determination theory [70] or other theoretical frameworks, future studies are needed which examine the stimulating effects of community-based making on competency development. The same caveat applies to the other attributes covered in the current study, all of which need to be explored through more in-depth research design(s).

VI. Conclusion

Makerspaces and making activities rely on scaffolding of children's learning to realize their full potential [71], [72]. While there is a considerable amount of advocacy for making education, there remains a lack of quantitative research with measurable outcomes regarding how children can enhance their learning through making [73]. Therefore, more empirical evidence is necessary to assess its effectiveness and improve learning experiences in various contexts. The study presented in this article investigated a making program contextualized within community youth centers in Hong Kong, in so doing examining the effectiveness of making activities as part of the competency development of school-age children. Positive findings, including the improvement of their IT skills, communication skills, and divergent thinking, as well as the correlations between these competencies and their technology acceptance, age, access to computers and ownership to mobile devices, resulted, supporting the hypothesis that community-based making experiences can provide learning opportunities that may not otherwise be feasible in the schooling context, and highlighting its importance in the personal growth of school-age children. Such alternative experiences can be synergized with structured learning in schools, leading to an all-round education that can develop the kinds of skills needed for the 21st century.

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