International Journal for Educational Media and Technology
2025, Vol.19, No. 1, pp.20-35

Empowering Girls in Robot Programming by Integrating the Video-Sharing Social Networking Service into Workshop Designs

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The underrepresentation of females in mechanical engineering highlights the need for educational strategies that engage girls in this field. This study aimed to design a robot programming workshop tailored to girls' interests by integrating engaging media technologies. Drawing on the content creation process of video-sharing social networking services, especially TikTok, four emotional components were incorporated into the workshop: Attachment to the robot, Attraction to the theme, a sense of Achievement in the work, and opportunities for Approval. The workshop was implemented with female teenagers, and the results showed a significant increase in intrinsic motivation, with a particularly large increase in confidence. These findings suggest that offering creative autonomy and opportunities for visible self-expression can transform initial interest into sustained engagement. This study contributes to educational media practices by demonstrating how media technology can be effectively integrated to enhance girls' motivation in robot programming.

Keywords: Robot programming, Learning resource, Video-sharing social networking service, Women in STEM fields

Introduction

Background

The underrepresentation of females in Science, Technology, Engineering, and Mathematics (STEM) fields has been a global concern (Yang & Warren, 2024). Within this context, Japan's particularly low percentage of female participation in engineering has been globally pointed out. According to Japanese statistics from the Ministry of Education, Culture, Sports, Science and Technology (MEXT, 2022a), which categorized STEM fields into 12 categories, mechanical engineering had the lowest proportion of female students at 5.6%. As a countermeasure, MEXT (2022b) has encouraged the establishment of reserved admission slots only for female applicants in university entrance exams in STEM fields. However, such affirmative action may merely serve to secure human resources and should be accompanied by efforts to foster female students' motivation (Yokoyama et al., 2024). According to Deci & Ryan (2000), intrinsic motivation, which is driven by personal interest, is essential for sustaining enthusiasm over time.

To attract students for continuous learning in STEM fields, the Japanese Ministry of Internal Affairs and Communications (MIC, 2018) has recommended their active participation in workshops as a preliminary step to capture attention. Research across various fields has also suggested that well-designed workshops can effectively foster intrinsic motivation (Effendi & Etikariena, 2018; Mizukami et al., 2012). Thus, in the field of mechanical engineering, it is necessary to design workshops that effectively stimulate intrinsic motivation. Regarding programming workshops using actual robots, which are closely related to mechanical engineering, there are often very few female participants in Japan. As a reason for this, several studies have pointed out gender biases: mechanical engineering is often perceived as male-oriented (Ikkatai et al., 2020), and engineering itself has historically been shaped by male-centric interests that fail to appeal to many females (Cheryan et al., 2017; Metaxa-Kakavouli et al., 2018). These findings suggest that conventional robot programming workshops have often been perceived as unapproachable to females.

Purpose of the Study

The purpose of this study is to explore the effectiveness of a robot programming workshop that integrates content already popular among female teenagers, with the goal of enhancing their motivation. This study focused on the potential of integrating the video-sharing Social Networking Service (SNS), which is widely used by Japanese teenage girls, into workshop design. First, based on the content creation process of video-sharing SNS, emotional components that could engage them were extracted. The workshop was then developed to incorporate these components, and its impact on intrinsic motivation was evaluated. To structure this research project, this study addresses the following research questions:

RQ1: Did the proposed workshop, based on video-sharing SNS, enhance the intrinsic motivation of female junior high school students toward robot programming?

RQ2: Were the emotional components embedded in the workshop effectively promoted?

By addressing **RQ1**, this study aims to contribute to increasing motivational pathways for female students in robot programming through workshops. Furthermore, by addressing **RQ2**, this study aims to capture the proposed workshop as a framework for development in future research, ultimately serving as a design guideline for implementing effective workshops in diverse educational settings.

Positioning of the Study

There have been systematic studies capturing trends in STEM education using robots: a review article analyzing 147 studies published from 2000 to 2018 (Anwar et al., 2019) and another analyzing 39 studies published from 2012 to 2021 (Darmawansah et al., 2023). Among these, gender differences in engagement have been mentioned, but there has been a lack of attention on how workshop design could reflect the specific interests of girls. Other studies have explored which types of robot exterior designs (Keller & John, 2020) or which types of workshop concepts (Mallik et al., 2023) tended to attract girls. However, strategies for significantly enhancing girls' motivation have not been thoroughly explored, and incorporating trends that are already popular among them could offer a promising direction. Therefore, by focusing on the integration of familiar and appealing media technologies, this study aims to provide new insights into educational design strategies. The findings could also offer valuable implications for other regions facing similar gender disparities in engineering.

Literature Review and Design of the Workshop

Workshop Targets and Attention to Emotions

McDonald (2016) indicates that students in many countries, including Japan, make decisions influencing STEM career participation around age 15, emphasizing the importance of focusing on STEM education around this period. Previous studies on robot programming have also targeted students aged 12-18 (Keller & John, 2020; Mallik et al., 2023). In this study, to foster intrinsic motivation before key career decision points, the workshop targeted Japanese female junior high school students aged 12-15.

In adolescent education, previous research has indicated the importance of paying attention to students' diverse emotions to enhance their learning motivation (Goetz et al., 2013; Schukajlow et al., 2023). Fagerlund et al. (2022) further reported that female students aged 13-14 demonstrated lower motivation toward programming than male students of the same age and emphasized that for female students, providing emotionally engaging learning experiences that diminish the prevalent views of programming as being unsuitable for their gender is particularly important to enhance girls' motivation. Thus, to design an engaging workshop for robot programming, which also tends to be of lower interest to girls, this study constructed a workshop framework by reviewing previous studies on emotional experiences related to video-sharing SNSs, robots, and classroom learning.

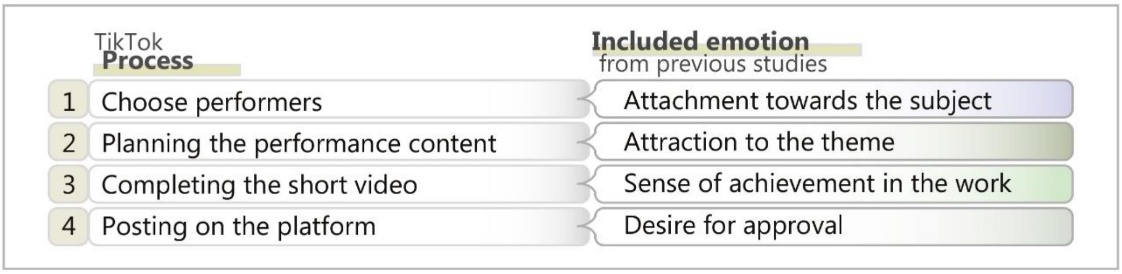
Features of the Video-Sharing SNS

The video-sharing SNS is a popular platform among teenagers, with TikTok being a representative example. According to the Mobile Society Research Institute (2024) in Japan, TikTok is the most popular platform among teenage girls, indicating notable gender differences in usage rate compared to text-based SNS and YouTube. A key feature that differentiates TikTok from other social media is that it offers a selection of music to choose from, allowing users to smoothly create short videos with music (Zeng et al., 2021). In other words, it enables them to create performances easily. Compared to YouTube, TikTok is more frequently used as a tool for self-expression (Al-Maroof et al., 2021). This characteristic aligns with findings that teenage girls tend to seek opportunities for social self-expression (Chen et al., 2022; Chua & Chang, 2016). So far, TikTok's widespread popularity has demonstrated its potential to deliver learning content that enhances educational outcomes for teenagers (Conde-Caballero et al., 2023). However, less attention has been paid to approaches that encourage students' active participation, not as passive recipients but as creators of content. Thus, the posting process on TikTok could serve as the basis for the effective workshop design.

Proposal of the A-Quartet Encouragements as the Workshop Foundation

Among the popular content types on TikTok, those applicable when moving robots through programming, such as dance performances and skits, were focused on. To construct the emotional foundation of an engaging robot programming workshop inspired by TikTok, the emotions included in each phase of the TikTok posting process and hypothesized to increase intrinsic motivation when applied to robot programming workshops were extracted as shown in Figure 1, drawing upon past studies on increased engagement with TikTok, robots, and classroom learning, which are discussed in the following paragraph.

Figure 1.
TikTok posting process and associated emotions.



Regarding process 1, on TikTok, various types of content can be found, such as dance covers and original videos. A common feature among many of these posts is the inclusion of personally meaningful elements to which users feel an attachment, which promotes a desire to express their identity—such as the creators themselves, their favorite objects, or places they have visited (Chua & Chang, 2016; Yang et al., 2021). Attachment is also known to be an important factor in encouraging interaction with robots, which are often perceived as difficult to approach (Law et al., 2022). Research in robot therapy has shown that forming attachments can alleviate fear toward robots, particularly among those unfamiliar with robots (Szondy & Fazekas, 2024; Wada et al., 2009). In particular, animal-shaped robots are effective in fostering attachment (Wada et al., 2009). Forming attachments requires a certain amount of time spent with them, but it has also been indicated that creating them originally can strengthen attachment (Norton et al., 2012). Especially for TikTok, a major factor in attracting young people's attention is its ability to enable self-expression (Chen et al., 2022; Chua & Chang, 2016). Thus, when applied in the robot programming workshop, adding their own original experiences through decorating robots that might otherwise be perceived as unapproachable could enhance attachment and serve as an effective initial step in boosting motivation to operate the robots as a means of self-expression.

Regarding process 2, as Elliot & Harackiewicz (1996) suggested, having an interest in the theme significantly contributes to enhancing students' learning motivation. On TikTok, users freely shape the content of their movies, and such creative themes that allow individuals to pursue their personal interests are considered to serve as a means of attracting them. For example, Alzubi & Nazim (2024) indicated that, compared to pre-determined assignments, assignments that allowed students to freely choose content aligned with their individual interests and thereby boosted motivation. Furthermore, Pezalla-Granlund et al. (2005) highlighted that girls were less motivated by competitive activities, emphasizing the importance of creative themes. Therefore, by allowing each student to freely shape the content through theme setting to create a performance, participants were expected to be attracted to the theme.

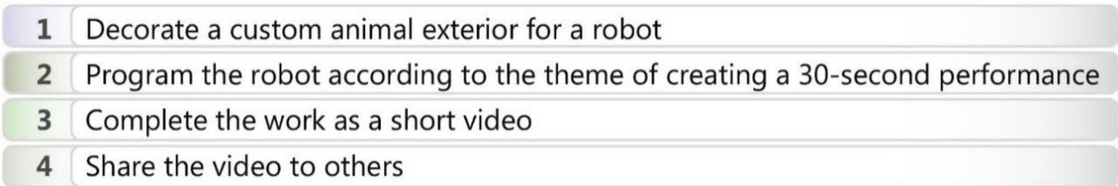
Regarding process 3, the sense of achievement is a crucial factor that leads to satisfaction, which is one of the key elements in motivating students to learn (Keller, 1987). Successful experiences have also been indicated to be important for enhancing self-efficacy (Bandura, 1997). However, the creative theme makes it difficult to provide a sense of achievement compared to goal-oriented themes, making it important to define completion in a tangible form. In this regard, TikTok has the characteristic of allowing users to feel a sense of achievement by completing what they have achieved in the form of videos that can be reviewed. This feature, enabling users to reflect on what they have achieved, is one of the crucial motivations for users to continue using TikTok (Omar & Wang, 2020). In addition, according to Koumura (2020), in a class on making digital content, female students tended to create videos that users could enjoy watching, rather than games. Therefore, in this workshop, by having each individual complete their work as a video, they could feel a sense of achievement in the work through recognizing their achievements.

Regarding process 4, the reason why girls post work on social media is known to be a desire for approval of their identity within a social context (Chen et al., 2022; Chua & Chang, 2016). Al-Khasawneh et al. (2022) also suggest that recognizing oneself among others by posting on TikTok induces a sense of belonging within a social context through the feeling of being accepted, which enhances the perceived value of their posts. Furthermore, a study that incorporated photo sharing into a programming workshop indicated that putting participants being seen by others enhanced participants' motivation, and reflection activities were promoted through comparing their work with others (Tsutsui & Takada, 2018). Thus, having a platform where individual work can be shown and accepted could be crucial for students to induce sustained motivation by allowing them to find value in their work in the context of others.

Building on the above-mentioned previous studies, four foundational components essential in increasing intrinsic motivation in robot programming for female junior high school students were hypothesized to capture the robot programming workshop design as a practical and versatile framework: Attachment to the robot, Attraction to the theme, a sense of Achievement in the work, and opportunities for Approval. Using the initials of these key terms, they were collectively named as the *A-quartet encouragements*, as shown in Figure 2. Accordingly, the workshop in this study was structured to include these components as shown in Figure 3.

Figure 2.
The A-quartet encouragements.

Figure 3.
Workshop process including the A-quartet encouragements.

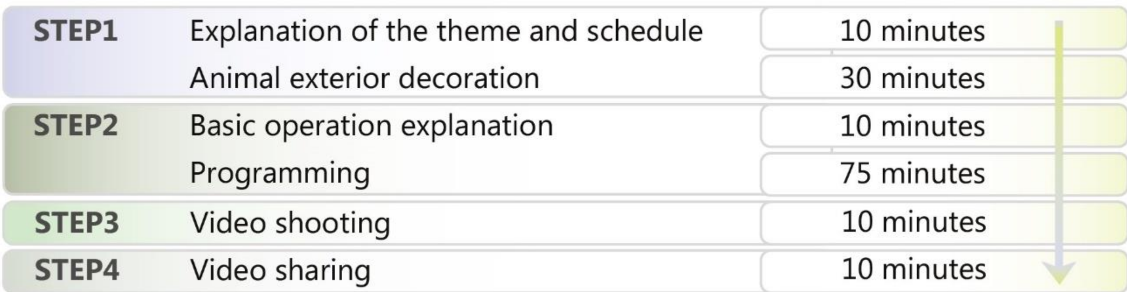


Detailed Planning for the Workshop

Workshop Schedule

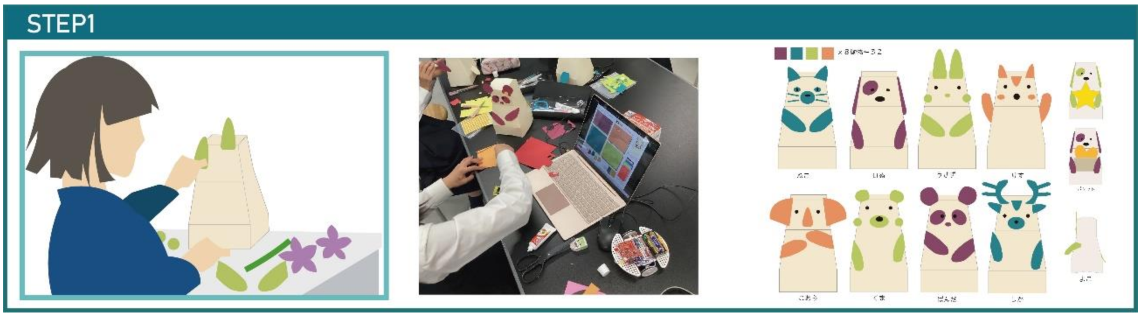
Figure 4 shows the workshop schedule in 150 minutes, incorporating the four processes in Figure 3. The time allocation was determined by conducting a preparation trial with university students.

Figure 4.
Workshop schedule.



STEP 1
At the beginning of the workshop, the theme and schedule of the workshop were explained. The theme was to create a 30-second performance featuring an animal robot. Participants could select music from three popular songs prepared in advance. After the explanation, the exterior of the robot was decorated in about 30 minutes, as shown in Figure 5. To avoid spending excessive time on creating the exterior, a pre-assembled paper shell was prepared as the animal's body. In addition, participants were able to choose from 32 different animal designs, with 8 types in 4 colors each. Depending on each choice, pre-cut paper parts were provided. After attaching the parts, participants freely added decorations according to their own ideas.

Figure 5.
STEP 1: Animal exterior decoration.



STEP 2
The next process was programming robots, as shown in Figure 6. The robot used for programming was the Beauto Rover ARM (Product of Vstone Co., Ltd.). It has dedicated software that enables beginners to easily attempt visual programming. After the basic operation explanation, participants started programming based on the performance they each envisioned. During the basic operation explanation, participants completed a simple program together by referring to slides projected on the screen and transferred the completed program to the robot to confirm whether it operated as intended. The slides used in this explanation are shown in Appendix 1. The instructor proceeded by checking whether each participant had completed the steps on each slide before moving on. Through the programming in STEP 2, participants learned through trial and error how to refine the robot's movements by connecting sequences, comparing their intended designs with the robot's actual behavior.

Figure 6.
STEP 2: Programming.

STEP 3
After the programming was completed, a video was taken by the smartphone prepared for the workshop, as shown in Figure 7. The shining effects were set to appear when taking videos. A detailed view of the video shooting is described in Appendix 2.

Figure 7.
STEP 3: Video shooting.

STEP 4
After all participants' videos were taken, each video was shown on a screen to showcase the achievements of the workshop, as shown in Figure 8. At the end of the workshop, a QR code was distributed, which provided access to the dedicated app where only those with the QR code could view videos from all the participants. Through this site, participants also got opportunities to show their uploaded videos to their families after going back home.

Figure 8.
STEP 4: Video sharing.

Method of the Workshop Implementation

Overview

The workshops were held five times between October and December 2023. Junior high schools were asked to host the workshop by explaining the research purpose, and three schools agreed to hold. Participants were recruited by announcing to female junior high school students that robot programming workshops for beginner female students would be held.

For the measurements, schools approved anonymous data and photo collection for research. Participants received documents explaining the purpose, anonymity, and data use. Only those who agreed completed the questionnaires. The contact information of the first author was also provided, and provisions were made to accommodate participants who wished to opt out of data collection later.

Participants

A total of 25 female junior high school students participated in the workshop. Prior to these workshops, the same workshop was conducted with 5 female junior high school students as a preliminary trial, asking the motivational items described in Figure 9 before and after the workshop. Based on these values, a power analysis was conducted using G*Power, and it was indicated that the sample size of 25 participants was appropriate to detect a significant difference before and after the workshop using the Wilcoxon signed-rank test ($\alpha = 0.05$) with a statistical power of 0.80.

The participants were students who had never experienced robot programming before the workshop. In addition, their prior experiences with programming itself were as follows: never experienced (3 participants), experienced once or twice at workshops, classes, etc. (16 participants), experienced three or more times in workshops, classes, etc. but not regularly (6 participants), and do it regularly as hobbies, club activities, etc. (No participants).

Measurements

To objectively measure whether the intrinsic motivation for robot programming was changed by the workshop, the ARCS evaluation index based on the ARCS model was used. The ARCS model, proposed by John M. Keller (1987), captures learner motivation from four aspects. It has been flexibly used in instructional design and evaluation, including measuring changes in students' intrinsic motivation through workshops (Kawai et al., 2007; Nakamura et al., 2021). In this study, based on the Japanese questionnaire translated by Suzuki (Keller & Suzuki, 2010), the intrinsic motivation for robot programming was assessed before and after the workshop using a 7-point Likert scale. The items are shown in Figure 9. When conducting the questionnaire before the workshop, participants did not know the contents of the workshop.

Figure 9.
Questionnaire about the intrinsic motivation for robot programming with ARCS.

Item	Question
Attention	Robot programming is interesting.
Relevance	Robot programming is relevant to me.
Confidence	Robot programming is something I can do.
Satisfaction	Robot programming is satisfying.

The questionnaire with sub-scale indexes of ARCS, which can be used to evaluate whether the workshop included strategies to promote intrinsic motivation (Keller & Suzuki, 2010), was also used to evaluate the workshop itself from the perspective of the ARCS model. Based on the questionnaire by Kogo and Suzuki (2000), 16 items were asked to answer about the workshop, as shown in Figure 10. These were answered after the workshop using a 7-point Likert scale.

Figure 10.
Questionnaire about the intrinsic motivation in the workshop with sub-scales of ARCS.

Item	Question
A. Attention	It was interesting.
A1. Perceptual Arousal	I didn't feel sleepy.
A2. Inquiry Arousal	It aroused my curiosity.
A3. Variability	It had variety.
R. Relevance	It was relevant to me.
R1. Familiarity	It was familiar to me.
R2. Goal Orientation	It was something I wanted to learn.
R3. Motive Matching	The process was enjoyable.
C. Confidence	I gained confidence.
C1. Learning Requirements	The goal was clear.
C2. Success Opportunities	I made steady progress.
C3. Personal Control	I was able to apply my creativity.
S. Satisfaction	It was satisfying.
S1. Natural Consequences	It was readily applicable.
S2. Positive Consequences	My achievements were recognized.
S3. Equity	The evaluation was consistent.

To measure whether the emotional components of the A-quartet encouragements were effectively promoted in the workshop, the items shown in Figure 11 were asked after the workshop using a 7-point scale.

Figure 11.
Questionnaire about the A-quartet encouragements in the workshop.

Item	Question
Attachment	I felt attached to the robot I created the exterior for.
Attraction	I was attracted to the theme of programming robots to perform.
Achievement	I felt a sense of achievement in completing the robot programming as a video.
Approval	I felt pleased to have an opportunity to share the video with others.

Results

Figure 12 shows examples of students' completed work. Each student created decorations and programming according to their own ideas, such as staging a gift-giving drama performance and presenting a dance performance. There were four pairs who performed together despite not being instructed to do so.

Figure 12.
Examples of completed works.

The results of the means (M), 95% confidence intervals (CI), and standard deviations (SD) for the items in Figure 9 are shown in Table 1. The same variables for the items in Figure 10 are shown in Table 2, and those for the items in Figure 11 are shown in Table 3. When the upper limit of the 95% CI exceeds 7, it is reported as 7. In Table 1, the Wilcoxon signed-rank test was conducted to compare responses before and after the workshop, and all items showed significant differences ($p < .001$). Effect sizes (r) for the non-parametric tests were also calculated, and according to Cohen's (1988) criteria, large effects ($r > .50$) were observed for the Attention, Relevance, and Confidence items, while a medium effect ($r > .30$) was observed for the Satisfaction item.

Table 1.
Results of the intrinsic motivation for robot programming with ARCS

Item	Before			After				
	M	95% *CI*	*SD*	*M*	95% *CI*	*SD*	*p*	*r*
Attention	6.20	[5.95, 6.45]	0.65	6.92	[6.81, 7]	0.28	< .001*	.59
Relevance	5.96	[5.63, 6.29]	0.84	6.84	[6.66, 7]	0.47	< .001*	.63
Confidence	4.60	[4.18, 5.02]	1.08	6.28	[5.97, 6.59]	0.79	< .001*	.69
Satisfaction	6.36	[6.11, 6.61]	0.64	6.84	[6.62, 7]	0.55	< .001*	.49

**Statistically significant*

Table 2.
Results of the intrinsic motivation in the workshop with the sub-scales of ARCS

Item	After		
	M	95% *CI*	*SD*
A. Attention	6.92	[6.81, 7]	0.28
A1. Perceptual Arousal	6.88	[6.71, 7]	0.44
A2. Inquiry Arousal	6.96	[6.88, 7]	0.20
A3. Variability	6.76	[6.56, 6.96]	0.52
R. Relevance	6.88	[6.75, 7]	0.33
R1. Familiarity	6.32	[6.10, 6.54]	0.56
R2. Goal Orientation	6.76	[6.56, 6.96]	0.52
R3. Motive Matching	6.88	[6.71, 7]	0.44
C. Confidence	6.24	[5.98, 6.50]	0.66
C1. Learning Requirements	6.20	[5.79, 6.61]	1.04
C2. Success Opportunities	6.56	[6.31, 6.81]	0.65
C3. Personal Control	6.84	[6.66, 7]	0.47
S. Satisfaction	6.96	[6.88, 7]	0.20
S1. Natural Consequences	5.84	[5.49, 6.19]	0.90
S2. Positive Consequences	6.68	[6.49, 6.87]	0.48
S3. Equity	6.60	[6.40, 6.80]	0.50

Table 3.
Results of the A-quartet encouragements in the workshop

Item	After		
	M	95% *CI*	*SD*
Attachment	6.76	[6.56, 6.96]	0.52
Attraction	6.80	[6.64, 6.96]	0.41
Achievement	6.68	[6.43, 6.93]	0.63
Approval	6.48	[6.18, 6.78]	0.77

Discussion

Discussion on RQ1

As shown in Table 1, all ARCS items showed a significant increase after the workshop, indicating that the workshop effectively enhanced intrinsic motivation. Notably, the Confidence had the lowest mean score before the workshop

(*M* = 4.60) compared to other items, but showed the largest increase (+ 1.68) afterward. This outcome aligns with previous studies suggesting that, due to persistent gender stereotypes in STEM fields, females are more likely than males to attribute failures in these fields to a lack of ability, which can easily lead to their negative emotional responses toward these fields (Murphy et al., 2019; Thoman, 2013). In this regard, the theme of the workshop in this study centered on the accomplishment of self-expression, allowing participants of any skill level to complete original works. This open-ended theme likely reduced the likelihood of experiencing a sense of failure. In other workshops designed to complete a unified goal, students can easily perceive differences in whether they have succeeded in completing a task and how quickly they did so. In contrast, the workshop design in this study encouraged each participant to create a project from exterior design to programming based on their own interests and to compile the final product into a video, which could shift the focus to what each participant was able to achieve, rather than what they failed to do—thereby reducing the likelihood of failure-related emotions. There was also the opportunity to show off completed videos to others, which may have contributed to a further sense of confidence by reinforcing a sense of achievement and recognition.

In Table 2, the items related to Attention in the workshop received generally high ratings, with the lower bound of the 95% *CI* for all four Attention-related items exceeding 6.50. Previous studies in science education noted that girls tended to be more interested in content that was closely related to their everyday experiences (Häussler & Hoffman, 2002; Smail, 1984). Thus, by incorporating trends popular among teenage girls, the workshop likely succeeded in capturing their attention. In addition, Cents-Boonstra et al. (2020) revealed that providing students with autonomy and active involvement at the beginning of lessons plays a crucial role in maintaining their attention. The workshop began with hands-on, familiar exterior design before moving on to programming—a process that requires time for explanation and is often perceived as challenging. This initial phase may have helped foster emotional attachment to the project, contributing to sustained attention throughout the workshop.

On the other hand, among all the items in Table 2, "S1. It was readily applicable" received a relatively low score, with the mean value being the only one below 6.00. This result implies that participants perceived limited clarity regarding the transferability of the acquired skills, which may partly explain why the effect size (*r*) for Satisfaction with robot programming in Table 1 remained medium. Although the primary focus of workshops was to offer enjoyable experiences for continuous learning, it is also necessary to design follow-up learning opportunities and clearly explain how the skills acquired in the workshop can be applied in subsequent steps.

Discussion on RQ2

As shown in Table 3, the four emotional components of the A-quartet encouragements incorporated into the workshop were perceived as being effectively promoted, receiving high ratings. As discussed earlier, the successful integration of these components, which were derived from TikTok, likely contributed to increased confidence in robot programming and heightened attention during the workshop. Especially, the workshop design, which fostered successful experiences and improved self-efficacy among female students, could have led to an enhanced sense of achievement and increased confidence. During a preparation trial with university students, some participants expressed concerns about feeling embarrassed to show their work to others. Based on this, it was anticipated the possibility that the Approval item could receive lower ratings among female teenagers as well. However, the results showed that although the Approval item received slightly lower ratings (*M* = 6.48) compared to the other items, it still remained high, with the lower bound of the 95% *CI* exceeding 6.00. This result suggests negative emotional responses associated with public presentation were unlikely to have occurred. One possible reason for this outcome can be found in the developmental characteristics of adolescence. According to Chua & Chang (2016), one reason for the popularity of social media among teenagers is that adolescence is a crucial period for identity formation, with girls tending to seek the development of their identities within a social context. Thus, designing learning experiences that support visible self-expression through original work may play an important role in fostering motivation, especially among female teenagers.

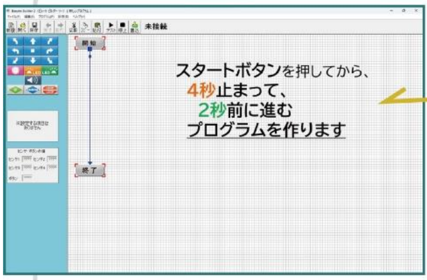
Conclusion

This study developed a new robot programming workshop integrating key aspects of video-sharing SNS, and the implementation of the workshop to female teenagers was found to enhance their intrinsic motivation toward robot programming. Based on the positive outcomes, it is essential to create more opportunities for female students to participate in similar workshops in the future. One limitation of this study is that the workshop was allowed to be conducted outside of regular class hours, with participation being voluntary. To extend the impact of this study, future research should explore ways to incorporate the workshop design into regular robot programming classes in schools to reach a broader range of female students. Through further examination and refinement, the A-quartet encouragements should be established as foundational components for designing workshops that effectively engage girls. Building on this, it would be valuable to explore the applicability of this framework to workshops covering other aspects of engineering education.

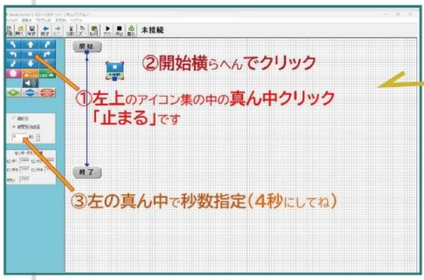
It is also important to explore what kinds of follow-up learning opportunities can be provided to sustain motivation. In the workshop conducted for this study, participants used visual programming and acquired skills in adjusting the robot's movements by connecting sequences and comparing them to the robot's actual behavior. Subsequent workshops can focus on the measurement and control, where participants construct programs that include conditional branching and loops, using sensor readings. The robot used in this study, the Beauto Rover ARM, supports the attachment of sensors and is capable of executing programs with IF statements and loops. Thus, one possible approach is to encourage students to work in pairs—as observed among several participants in Figure 12—creating skits by reading sensor values and coordinating their robots accordingly. Furthermore, the Beauto Rover ARM also supports manual robot assembly and text programming in the C language, allowing for the natural integration of more skills related to mechanical engineering into workshop activities. For example, students can learn how to expand their robots' capabilities by modifying the internal structure to align with their creative intentions or by writing custom programs using text-based code. Building on the reduced psychological barriers to engagement observed in the workshop proposed in this study, future studies should investigate the development of step-by-step workshop designs that provide enjoyable learning experiences related to the mechanical engineering field and illustrate how these experiences connect to real-world applications in this field.

Appendix 1. The slides used in this explanation.

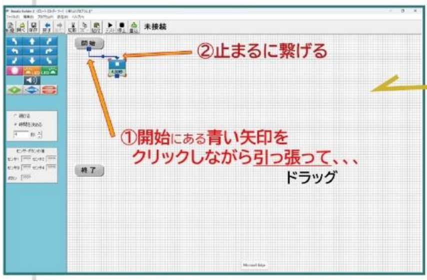
[Let’ s create a sample program together]



We’ ll program the robot to stop for 4 seconds and then move forward for 2 seconds, after pressing the start button.

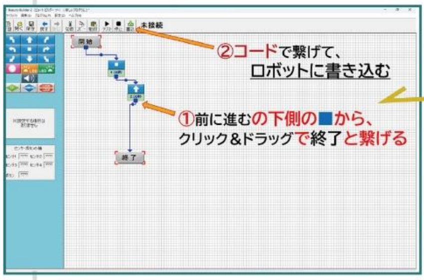


How to add a "Stop" block:
① Click the "Stop" icon.
② Click the white space (on the canvas).
③ Set the duration to 4 seconds.



How to connect blocks:
① Click the blue square of the "Start" block.
② Drag it to the instruction block.

Add the "Move Forward" block in the same way.

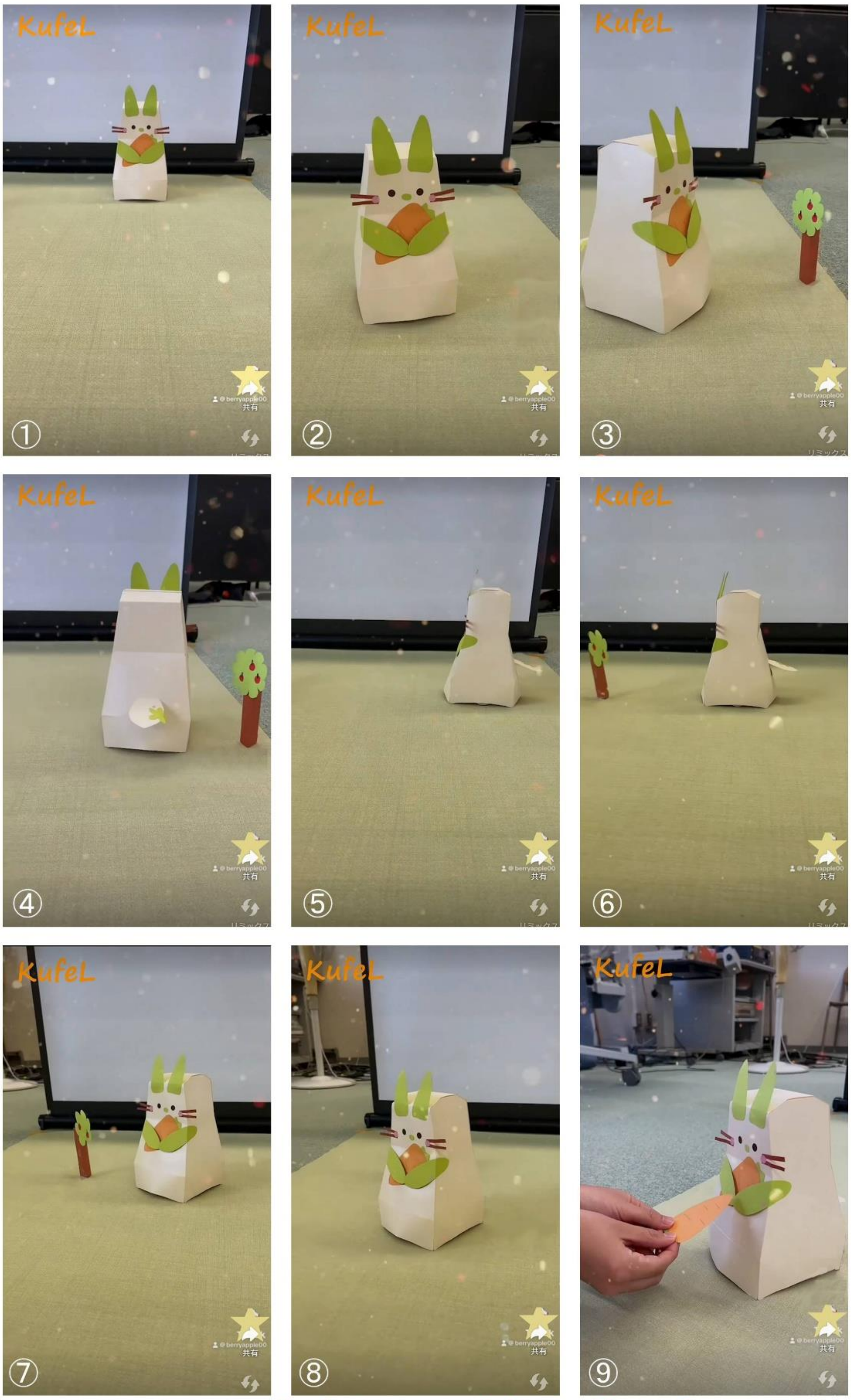


Complete the program and write it to the robot:
① Connect the "Move Forward " block to the "End" block.
② Connect the code and write it to the robot.

Other movements (introduction on slides only):

[And then, create your original program through trial and error]

Appendix 2. Overview of the Video Shooting.



An example of a 30-second video with music
Content: A rabbit searching for carrots in the forest

References

Al-Khasawneh, M., Sharabati, A. A., Al-Haddad, S., Tbakhia, R., & Abusaimeh, H. (2022). The adoption of TikTok Application Using TAM Model. *International Journal of Data and Network Science, 6,* 1389-1402. https://doi.org/10.5267/j.ijdns.2022.5.012

Al-Maroof, R., Ayoubi, K., Alhumaid, K., Aburayya, A., Alshurideh, M., Alfaisalg, R., & Salloumh, S. (2021). The acceptance of social media video for knowledge acquisition, sharing and application: A comparative study among YouTube users and TikTok users' for medical purposes. *International Journal of Data and Network Science*, *5*(3), 197–214. https://doi.org/10.5267/j.ijdns.2021.6.013

Alzubi, A. A. F.& Nazim, M. (2024). Students' intrinsic motivation in EFL academic writing: Topic-based interest in focus. *Heliyon*, *10*(1). https://doi.org/10.1016/j.heliyon.2024.e24169

Anwar, S., Bascou, N. A., Menekse, M., & Kardgar, A. (2019). A Systematic Review of Studies on Educational Robotics. *Journal of Pre-College Engineering Education Research*, *9*(2), Article 2. https://doi.org/10.7771/2157-9288.1223

Bandura, A. (1997). *Self-efficacy: The exercise of control.* W H Freeman/Times Books/ Henry Holt & Co.

Cents-Boonstra, M., Lichtwarck-Aschoff, A., Denessen, E., Aelterman, N., & Haerens, L. (2020). Fostering student engagement with motivating teaching: an observation study of teacher and student behaviours. *Research Papers in Education*, *36*(6), 754–779. https://doi.org/10.1080/02671522.2020.1767184

Chen, S., van Tilburg, W. A. P., & Leman, P. J. (2022). Women's Self-Objectification and Strategic Self-Presentation on Social Media. *Psychology of Women Quarterly*, *47*(2), 266-282. https://doi.org/10.1177/03616843221143751

Cheryan, S., Ziegler, S. A., Montoya, A. K., & Jiang, L. (2017). Why are some STEM fields more gender balanced than others? *Psychological Bulletin*, *143*(1), 1–35. https://doi.org/10.1037/bul0000052

Chua T. H. H., & Chang L. (2016). Follow me and like my beautiful selfies: Singapore teenage girls' engagement in self-presentation and peer comparison on social media. *Computers in Human Behavior*, *55*, 190–197. https://doi.org/10.1016/j.chb.2015.09.011

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Conde-Caballero, D., Castillo-Sarmiento, C. A., Ballesteros-Yánez, I., Rivero-Jiménez, B., & Mariano-Juárez, L. (2024). Microlearning through TikTok in Higher Education. An evaluation of uses and potentials. *Education and Information Technologies*, *29*, 2365-2385. https://doi.org/10.1007/s10639-023-11904-4

Darmawansah, D., Hwang, GJ., Chen, MR. A., & Liang, J. C. (2023). Trends and research foci of robotics-based STEM education: a systematic review from diverse angles based on the technology-based learning model. *International Journal of STEM Education*, *10*. https://doi.org/10.1186/s40594-023-00400-3

Deci, E. L., & Ryan, R. M. (2000). The "What" and "Why" of Goal Pursuits: Human Needs and the Self-Determination of Behavior. *Psychological Inquiry*, *11*(4), 227–268. https://doi.org/10.1207/S15327965PLI1104_01

Effendi, R. T., & Etikariena, A. (2018). The Relationship Of Improving Intrinsic Motivation On Turnover Intention By Using Job Crafting Workshop for Employee At Division X in a food company. *Proceedings of the 1st International Conference on Intervention and Applied Psychology*, 300-308. https://doi.org/10.2991/iciap-17.2018.26

Elliot, A. J., & Harackiewicz, J. M. (1996). Approach and avoidance achievement goals and intrinsic motivation: A mediational analysis. *Journal of Personality and Social Psychology*, *70*(3), 461–475. https://doi.org/10.1037/0022-3514.70.3.461

Fagerlund, J., Leino, K., Kiuru, N., & Niilo-Rämä, M. (2022). Finnish teachers' and students' programming motivation and their role in teaching and learning computational thinking. *Frontiers in Education*, *7*. https://doi.org/10.3389/feduc.2022.948783

Goetz, T., Lüdtke, O., Nett, U. E., Keller, M. M., & Lipnevich, A. A. (2013). Characteristics of teaching and students' emotions in the classroom: investigating differences across domains. *Contemporary Educational Psychology*, *38*(4), 383–394. https://doi.org/10.1016/j.cedpsych.2013.08.001

Häussler, P., & Hoffmann, L. (2002). An intervention study to enhance girls' interest, self- concept, and achievement in physics classes. *Journal of Research in Science Teaching*, *39*(9), 870–888. https://doi.org/10.1002/tea.10048

IIkkatai, Y., Minamizaki, A., Kano, K., Inoue, A., McKay, E., & Yokoyama, H. M. (2020). Gender-biased public perception of STEM fields, focusing on the influence of egalitarian attitudes toward gender roles. *Journal of Science Communication*, *19*(1). https://doi.org/10.22323/2.19010208

Kawai, K., Yamazaki, Y., & Nakayama, K. (2007). Development and formative evaluation of a Web-based stress management program to promote psychological well-being, *Japanese Journal of Health and Human Ecology*, *73*(4), 137-152. https://doi.org/10.3861/jshhe.73.137

Keller, L., & John, I. (2020). Motivating Female Students for Computer Science by Means of Robot Workshops. *International Journal of Engineering Pedagogy*, *10*(1), 94-108. https://doi.org/10.3991/ijep.v10i1.11661

Keller, J. M., & Suzuki, K. (Trans.) (2010). *Motivational design for learning and performance : the ARCS model approach*. Kitaoji Syobo.

Keller, J. M. (1987). Development and use of the ARCS model of instructional design. *Journal of Instructional Development*, *10*(2), 2–10. https://doi.org/10.1007/BF02905780

Kogo, C., & Suzuki, K. (2000). An analysis of the structure of course evaluation items based on ARCS motivation model(2). *Proceedings of ICCE/ICCAI 2000, 8th International Conference on Computers in Education/International Conference on Computer-Assisted Instruction 2000*, 1577-1158.

Koumura, M. (2020). Practical and Survey Report of a Programming Workshop for Girls. *Research Report of Information Education*, *2*, 17-23. https://doi.org/10.24711/rrie.2.0_17

Law, T., Chita-Tegmark, M., Rabb, N., & Scheutz, M. (2022). Examining Attachment to Robots: Benefits, Challenges, and Alternatives. *ACM Transactions on Human-Robot Interaction*, *11*(4), 1-18. https://doi.org/10.1145/3526105

Mallik, A., Liu, D. & Kapila, V. (2023). Analyzing the outcomes of a robotics workshop on the self-efficacy, familiarity, and content knowledge of participants and examining their designs for end-of-year robotics contests. *Education and Information Technologies, 28*, 7225-7264. https://doi.org/10.1007/s10639-022-11400-1

McDonald, C. V. (2016). STEM Education: A review of the contribution of the disciplines of science, technology, engineering and mathematics. *Science Education International*, *27*(4), 530-569.

Metaxa-Kakavouli, D., Wang, K., Landay, J. A., & Hancock, J. (2018). Gender-Inclusive Design: Sense of Belonging and Bias in Web Interfaces. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. 1–6. https://doi.org/10.1145/3173574.3174188

Ministry of Education, Culture, Sports, Science and Technology (MEXT). (2022a, December 21). *[Reiwa 4-nen Gakkou Kihon Chousa] 2022 School Basic Survey*. https://www.mext.go.jp/content/20221221-mxt_chousa01-000024177_001.pdf (accessed April 18, 2025)

Ministry of Education, Culture, Sports, Science and Technology (MEXT). (2022b, June 6). *[Reiwa 5-nendo Daigaku Nyūgakusha Senbatsu Jisshi Yōkō ni Tsuite] Implementation Guidelines for University Entrance Examinations in 2023*. https://www.mext.go.jp/content/20220603-mxt_daigakuc02-000005144_1.pdf (accessed April 18, 2025)

Ministry of Internal Affairs and Communications (MIC). (2018, June 5). *[Puroguramingu Jinzai Ikusei no Arikata ni Kansuru Chousa Kenkyuu Houkokusho] Research Report on the Approach to Nurturing Programming Talent*. https://www.soumu.go.jp/main_content/000424363.pdf (accessed April 18, 2025)

Mizukami, S., Awahara, T., & Sakurai, Y. (2012). A Study on the Intrinsic Motivation Program in the Workshop −Trial and verification on the workshop for the welfare service worker−. *AIJ Journal of Technology and Design*, *18*(38), 381-386. https://doi.org/10.3130/aijt.18.381

Mobile Society Research Institute. (2024, December 23). *[10-dai josei 6-wari cho ga TikTok riyo: 10~20-dai de yaku 3-wari ga 1-nichi 10-kai ijo riyo]More than 60% of teenage girls use TikTok, and about 30% of people in their teens and twenties use it more than 10 times a day.* https://www.moba-ken.jp/project/service/20241223.html (accessed April 18, 2025)

Murphy, S., MacDonald, A., Wang, C.A., & Danaia, L. (2019). Towards an Understanding of STEM Engagement: a Review of the Literature on Motivation and Academic Emotions. *Canadian Journal of Science, Mathematics and Technology Education*, *19*, 304–320. https://doi.org/10.1007/s42330-019-00054-w

Nakamura, K., Misono, T., & Watanabe, Y. (2021). Development of an Effective and Engaging Instructional Design and Technology Course. *International Journal for Educational Media and Technology*, *15*(1), 90-104.

Norton, M. I., Mochon, D., & Ariely, D. (2012). The IKEA Effect: When Labor Leads to Love. *Journal of Consumer Psychology*, *22*(3), 453–460. https://doi.org/10.1016/j.jcps.2011.08.002

Omar, B., & Wang, D. (2020). Watch, Share or Create: The Influence of Personality Traits and User Motivation on TikTok Mobile Video Usage. *International Journal of Interactive Mobile Technologies*, *14*(4), 121-137. https://doi.org/10.3991/ijim.v14i04.12429

Pezalla-Granlund, M., Rusk, Resnick, M., & Berg, R. (2005). Rethinking Robotics: Learning through Creative Engineering. *ASTC Conference*.

Schukajlow, S., Rakoczy, K., & Pekrun, R. (2023). Emotions and motivation in mathematics education: Where we are today and where we need to go. *ZDM Mathematics Education*, *55*, 249–267. https://doi.org/10.1007/s11858-022-01463-2

Smail, B. (1984). *Girl-friendly Science: Avoiding Sex Bias in the Curriculum*. Longman.

Szondy, M., & Fazekas, P. (2024). Attachment to robots and therapeutic efficiency in mental health. *Frontiers in Psychology*, *15*. https://doi.org/10.3389/fpsyg.2024.1347177

Thoman, D. B., Smith, J. L., Brown, E. R., Chase, J., & Lee, J. Y. K. (2013). Beyond performance: A Motivational Experiences Model of Stereotype Threat. *Educational Psychology Review*, *25*(2), 211–243. https://doi.org/10.1007/s10648-013-9219-1

Tsutsui, K., & Takada, H. (2018). A classroom SNS to promote reflective activity in programming learning for children. *Research and Practice in Technology Enhanced Learning*, *13*. https://doi.org/10.1186/s41039-018-0069-9

Wada, K., Shibata, T., & Kawaguchi, Y. (2009). Long-term robot therapy in a health service facility for the aged -A case study for 5 years-. *2009 IEEE International Conference on Rehabilitation Robotics*, 930-933. https://doi.org/10.1109/ICORR.2009.5209495

Yang, J., & Warren, S. (2024). Can Social Interactions Support Women in STEM Education? The Data Mining Approach. *International Journal for Educational Media and Technology*, *18*(2), 24-35.

Yang, M., Zhang, W., Ruangkanjanases, A., & Zhang, Y. (2021). Understanding the Mechanism of Social Attachment Role in Social Media: A Qualitative Analysis. Frontiers in psychology, *12*, 720880. https://doi.org/10.3389/fpsyg.2021.720880

Yokoyama, H. M., Ikkatai, Y., McKay, E., Inoue, A., Minamizaki, A., & Kano, K. (2024). Can affirmative action overcome STEM gender inequality in Japan? Expectations and concerns. *Asia Pacific Business Review*, *30*(3), 543–559. https://doi.org/10.1080/13602381.2024.2320547

Zeng, J., Abidin, C., & Schäfer, M. (2021). Research perspectives on TikTok and its legacy apps: introduction. *International Journal of Communication*, *15*. https://doi.org/10.5167/uzh-205427