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An Assessment of Engagement, Experience, and Attitudes after Participation in the Girls in Control Workshop ⋆

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Abstract: Stereotypes based on gender often discourage women and gender-diverse people from pursuing studies in Science, Technology, Engineering, and Mathematics (STEM) during their secondary and tertiary education. Control engineering exemplifies a field where women and gender-diverse people face underrepresentation across all academic stages. The Girls in Control (GiC) workshop addresses this issue by focusing on 10-to-15-year-old girls, aiming to impart understandable and engaging knowledge about control engineering to stimulate an interest in pursuing STEM. In this paper, we present the results from a questionnaire that 53 participants of the GiC workshop participated in. We break up the assessment of the responses into their ability to comprehend basic control engineering concepts, their perceptions of the workshop, and their attitudes towards STEM. Most of the participants could grasp basic control concepts after participating in the workshop, and their general experience was rated very positively with only slight variations based on whether the participants had previous programming experience. Additionally, the overall perception towards STEM was very positive with the girls in an older age bracket rating a higher significance to the role of STEM in helping society.

Keywords: Control engineering education, virtual teaching, internationalization of control education

1. INTRODUCTION

Recent years have seen a significant increase in efforts to close the gender gap in STEM. Although the statistics on the percentages of women in engineering at a bachelor level vary depending on discipline and country, National Science Board (2018) give a general indication of 10 to 40 percent female students in engineering. More specifically, control engineering suffers from an under-representation of women at all stages of education and academia from the student to faculty level (Annaswamy, 2020). In control engineering organizations such as International Federation of Automatic Control (IFAC) and the Institute of Electrical and Electronics Engineers (IEEE) control systems society, about 10 % of the technical board members are women. There is thus an obvious need to encourage a strong pipeline of women and gender-diverse people from studies through to pursuing a career in academia.

Causes for the obvious gender imbalance in STEM disciplines across the board are postulated to be associated with gender stereotypes Schuster and Martiny (2017). In the past, STEM subjects have been perceived to be more masculine, which often discourages girls from identifying with them due to a conflict with their *self-image* – a particularly crucial phenomenon during adolescence Makarova et al. (2019). This perception can even appear in children as early as 6 years of age – before they even have an understanding of STEM subjects Makarova et al. (2019). Moreover, although TIMSS (2019) shows that there is no significant difference in performance between genders in standardized secondary-level mathematics and science tests, girls tend to report lower self-efficacy; i.e., a lower belief in their capabilities; in mathematics and science compared to boys Dubetz and Wilson (2013). It is evident that to improve the STEM pipeline and combat stereotypes in science and engineering, interventions should start at a late-primary to early-secondary level of education.

Many existing programs for addressing gender diversity in STEM are localized, even though the problem is on a global scale. To address this problem, the GiC program was developed in 2020; during the COVID-19 pandemic; to educate girls and gender-diverse children about control engineering to attract more women and diverse people into the fields globally. The GiC workshop targets 10-to-15-year-old girls and gender-diverse children and focuses on control engineering-specific problems to demonstrate the diverse nature of control engineering. The workshop provides the participants with a taste of science and mathematics through control engineering problems and encourages them to consider a career in STEM. Furthermore, with the goal of reaching participants globally, the GiC workshop aims to remove language barriers by running in

⋆ The Girls in Control workshop is sponsored by the IFAC Foundation.

18 languages [1] on a virtual platform. The workshop, thus, provides an educational experience without the barrier of language or country of residence. A summary of the GiC workshop can be found in Jackson et al. (2021); Knorn et al. (2021).

In this manuscript, we present the statistical results from a questionnaire that was sent to a portion of GiC participants to assess their comprehension, general experience, and perception of science after participating in the workshop. We look here at the difference in responses based on age group, country of residence, and programming experience and discuss the results of particular meaning.

2. THE WORKSHOP LAYOUT

The workshop runs in a logical order where we first discuss control concepts and define some of the terminology that we adopt throughout the workshop. The participants then work through a control problem where they design a game of chase in a graphical programming language, i.e., Scratch. Finally, we invite a female or gender-diverse guest speaker to present their work and to interact with the participants by answering questions on what it's like to be a control engineer.

2.1 Feedback, Measurements, Controllers, and Actuators

From the beginning of the workshop, it is important to define the main elements of control loops including feedback, measurements, controllers, and actuators. We begin by discussing different "human in the loop" examples that are familiar from their daily lives. As an example, we discuss taking a shower, which we have found to be a (mostly [2]) universal example and can be explained by using the block diagram in Fig. 1. In this example, we define the important elements of a feedback loop:

The plant is the system that we wish to change because it does not meet the specifications. In Fig. 1 our plant is a shower and is represented by the shower icon.

The sensor detects or measures a physical quantity. In Fig. 1 our sensor is our hand feeling the temperature of the water.

The controller uses the sensed value compares it to an expected value and decides how to change the operation of the plant. In Fig. 1 the controller is indicated by the brain icon because when we shower, the temperature information is processed by our brain and registered to be too hot, too cold, or just right. The brain then decides on the appropriate adjustment to make the water colder, hotter, or no change, respectively.

The actuator physically creates change in the system. In Fig. 1 the actuator is the pair of taps that indicate hot and cold because we adjust the taps to change the temperature of the water.

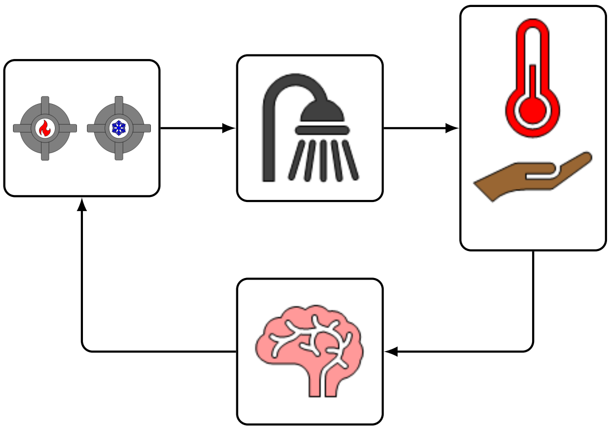


Figure 1. Block diagram of the shower feedback cycle.

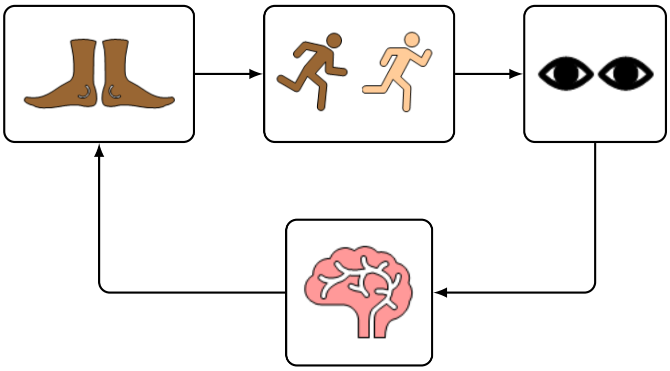


Figure 2. Block diagram of the feedback cycle when playing a game of chase.

2.2 The Control Task

Using the fundamental understanding of a feedback loop and forming it in an engineering block diagram allows the extension of this system into other control examples. In the control task, we encourage the participants to consider the feedback loop for another "human in the loop" example – playing a game of chase. In a game of chase (also known as tag or tips), one person is *it* and runs after the other players trying to tag them. The first person tagged is the new person who is *it* and the game continues.

We use the block diagram in Fig. 2 to again help explain the role of the plant, the sensor, the controller, and the actuator. In Fig. 2, the task is to chase after the other player/s, we use our eyes as the sensor to see where we need to run, and we use our brain to interpret this information and determine in which direction we should run, and we use our legs to physically run after the other player.

To implement this game, the girls then move on to using Scratch, a graphical drag-and-drop programming language accessible at `https://scratch.mit.edu/` to implement their first controllers for an automated game of chase. The girls are encouraged to implement advanced features such as scoring systems, and adaptive dynamics, and consider how to implement more advanced control techniques.

[1] The current workshop languages include: Bangla, Chinese, English, French, German, Hindi, Indonesian, Italian, Japanese, Korean, Norwegian, Portuguese, Romanian, Russian, Turkish, Spanish, Swedish, Thai.

[2] In some countries, such as Brazil, the water is heated while flowing through a heating coil built into the shower head. This usually only allows for the settings: on (winter) or off (summer). The example where the temperature is carefully adjusted may not be understood well by the participants from these countries.

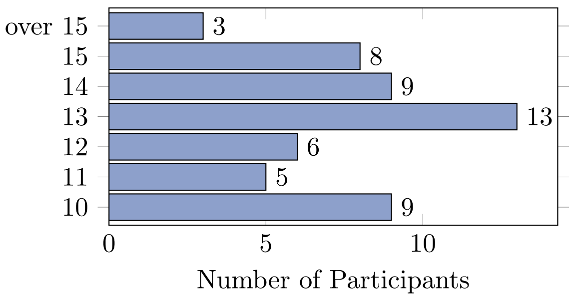


Figure 3. Participant ages ranging from 10 to over 15 years.

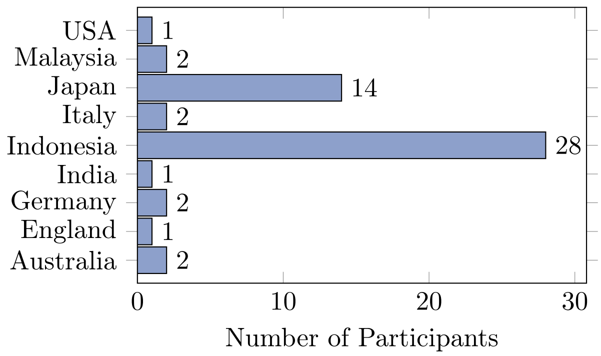


Figure 4. Participant country of residence.

3. THE QUESTIONNAIRE AND PARTICIPANT FEEDBACK

After completion of the workshop, we encouraged some participants to respond to a questionnaire about their experience and appraise the workshop. We do so by asking a range of questions about their comprehension, experience, and their attitude towards STEM. In this section, we state the questions and present the significant results obtained from the questionnaire.

3.1 Demographics

The questionnaire was answered by 53 girls from 10 years of age with a mean age of 12.83 and a standard deviation of 1.83; between fourth and eleventh grade at school; residing in nine different countries; mainly Japan (26 %) and Indonesia (53 %). Figures 3–4 show the demographics of the participants who responded to the questionnaire.

We additionally asked the participants to indicate how much programming experience they had to see if previous programming experience helped or deterred them from engaging in the workshop. Fig. 5 indicates the self-reported times that a participant had previously participated in a programming activity, i.e. Scratch, Alice, Lego Robots, Python, where 58 % of the participants have programming experience. The figure additionally bins the ages of the participants to show that age did not affect how likely they were to have programming experience.

3.2 Comprehension

In this section, we present the results of how the workshop participants responded to comprehension questions about a control system to see if the explanations given throughout the workshop were successful. The participants were

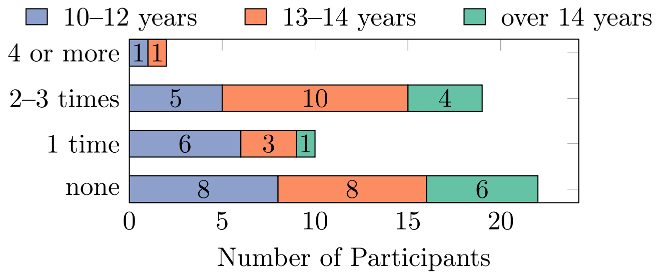


Figure 5. The previous programming experience for different age groups reported as the number of times they have previously used a programming language.

asked to consider a control system for balancing a stick vertically in the palm. They were then asked the following:

1. What is the sensor?
2. What is the controller?
3. What is the actuator?

The answers to comprehension questions 1–3 are shown in Fig. 6. The results are shown with an additional binning of the results based on the participants' previous programming experience.

3.3 Evaluation of the Workshop

The participants were asked a series of questions about their overall impression during the workshop (inspired by the FunQ questionnaire in Tisza and Markopoulos (2021)) to help to continue to improve to workshop. In this section, we assess the responses based on the participants' previous programming experience to assess whether the workshop is more engaging and enjoyable to girls without previous exposure to programming. The workshop impression statements included the following:

1. I found the GiC workshop *fun.*
2. I found the GiC workshop *easy to follow.*
3. I found the GiC workshop *pleasant.*
4. I found the GiC workshop *exciting.*
5. The GiC workshop is *something I want to do again.*

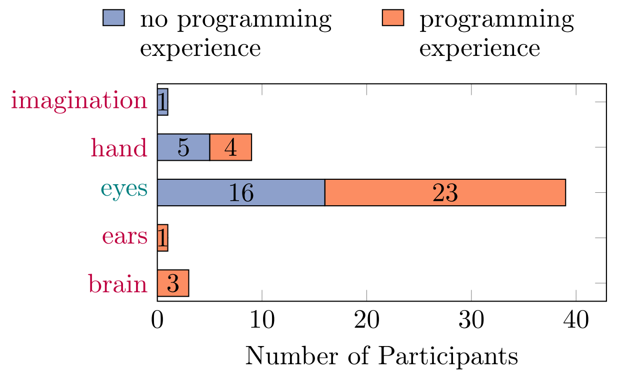
Figures 8–7 show the participants' responses to the workshop impression statements. The results are binned based on the participants' previous programming experience.

3.4 Workshop Experience

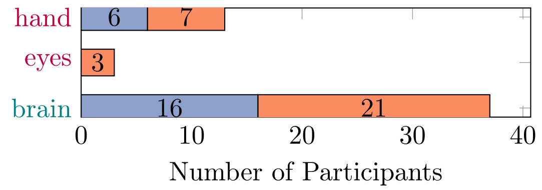
To evaluate the workshop experience, we asked the participants to respond to the following statements inspired by the questionnaire in Christidou et al. (2021):

1. During the GiC workshop, *I learned new things.*
2. During the GiC workshop, *I enjoyed discovering new things.*
3. During the GiC workshop, *I was curious.*
4. During the GiC workshop, *I found that Scratch was a good way to learn how to program.*

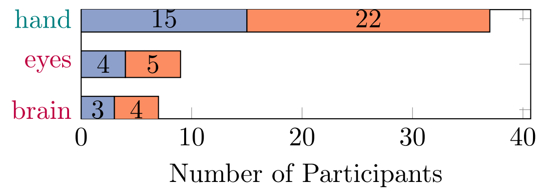
These questions are used to help adjust workshop content and assess how effectively the workshop content is delivered. The responses are again presented with separate



(a) Question: *What is your sensor?* Correct answer: *Eyes*



(b) Question: *What is your controller?* Correct answer: *Brain*



(c) Question: *What is your actuator?* Correct answer: *Hand*

Figure 6. Participant responses to the respective questions when considering the scenario of *balancing a stick vertically in the palm of your hand*. Correct answers are indicated in green and incorrect answers in red.

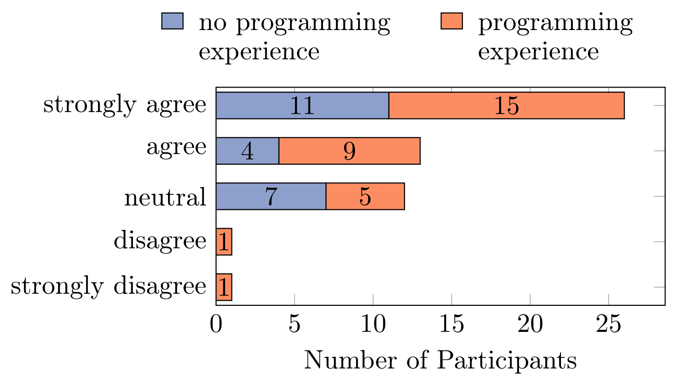
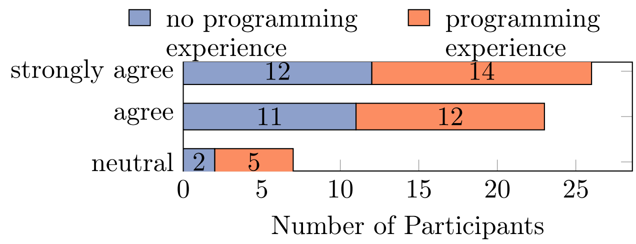
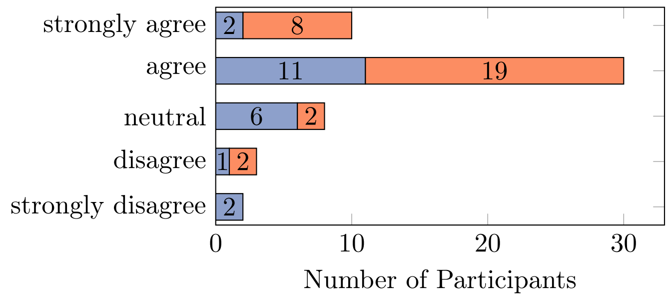


Figure 7. Participant responses to the question: *The GiC workshop is something I want to do again.*.

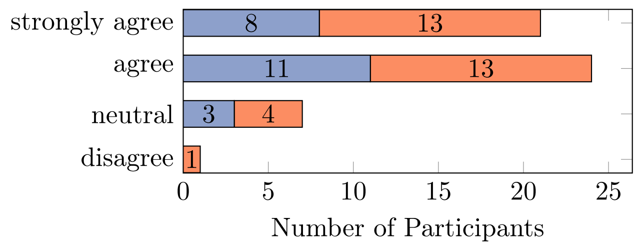
bins based on the participants' previous programming experience to, again, evaluate the impact of programming experience on workshop perceptions. The responses are presented in Fig. 9 where the results are binned based on the participants' previous programming experience.



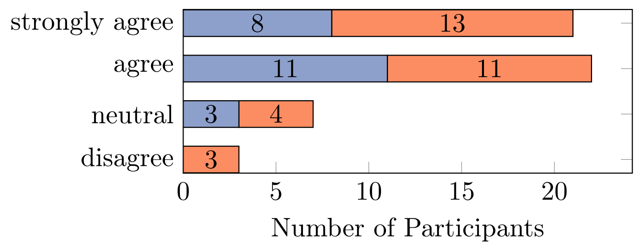
(a) *fun*



(b) *easy to follow*



(c) *pleasant*



(d) *exciting*

Figure 8. Participant responses to the respective statements of *I found the GiC workshop....*

3.5 Attitudes towards Science and Engineering

Lastly, the questionnaire covered questions regarding the participants' comprehension of the importance of STEM and the prevalence of control in daily life. We present the responses to these questions binned into age groups as we are interested in understanding the impact of age on perceptions of STEM to focus on the best time to encourage girls into STEM. To evaluate these perceptions of science and engineering, we asked the following questions:

1. Control and feedback cycles are present in many aspects of my daily life.
2. Science and technology, in particular control engineering, can help understand and solve important problems.

3. Learning about science and technology can help me to solve important problems of our time, e.g., medical treatment or protecting our environment.

For the responses to the statements see Fig. 10 where the results are binned based on the participants' ages.

4. DISCUSSION OF THE QUESTIONNAIRE RESPONSES

In this section, we discuss the participants' responses to the questionnaire as presented in Section 3. We further make some comments on the meaning of these results and critically evaluate the statistical significance of the results.

4.1 Discussion of the Comprehension

When asked to identify the sensor (Fig. 6(a)), controller (Fig. 6(b)), and actuator (Fig. 6(c)) of a particular control system, over half of the participants gave the correct answer for all of the questions regardless of their previous programming experience. The results here conclude that the conceptual understanding of a feedback loop and the components of a controller are generally well understood.

4.2 Discussion of the Workshop Evaluation

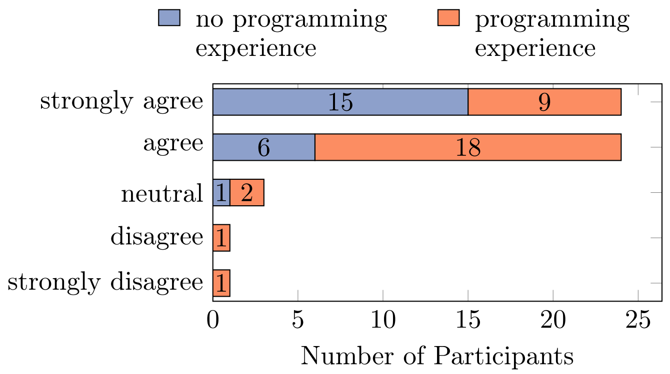
The questions regarding the participants' impression of the workshop ("fun", "exciting", and "pleasant") were all in the same vein and resulted in similar responses from the participants. Over 80 % of the girls agreed or strongly agreed – 87 % "fun" (Fig. 8(a)), 81 % "exciting" (Fig. 8(d)), 85 % "pleasant" (Fig. 8(c)) – for all three statements. Girls with programming experience are, however, over-represented for feeling neutral or disagreeing that the workshop was "fun" and "exciting". Thus, girls who hadn't had previous experience in similar workshops found the workshop to be more "fun" and "exciting" than girls who had participated in similar workshops.

Even though the great majority of participants without programming experience considered the workshop a nice activity only 57 % of them agreed or strongly agreed that the workshop was "easy to follow". This stands in contrast to the girls with earlier activities in programming of whom 87 % claimed to agree or strongly agree with the workshop being easy to follow; see Fig. 8(b). However, despite these difficulties with the understandability of the workshop for the girls without previous programming experience, two out of three of them said that the course was something they wanted to do again, where the percentage for all participants is 73 %; see Fig. 7.

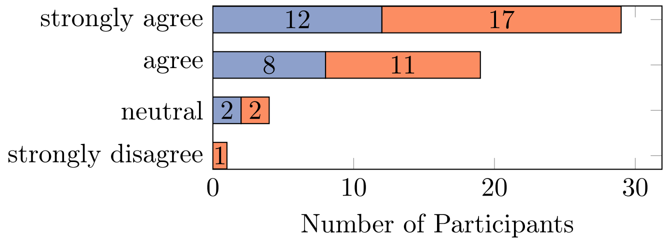
4.3 Discussion of the Workshop Experience

From Figures 9(a)–9(b), we see that 90 % of the participants; particularly the participants without previous programming experience; learned new things during the workshop and found learning new things enjoyable. Less so, with 83 % (Fig. 9(c)), of the participants reported feeling curious throughout the workshop.

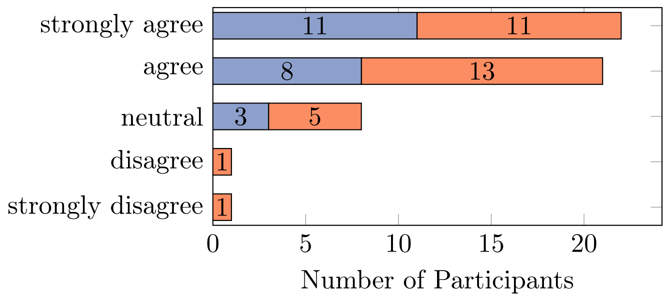
The majority, 85 % (Fig. 9(d)) considered Scratch to be a good way to learn how to program. The girls without programming experience even evaluated Scratch to be more helpful than girls without programming experience with 90 %, and 83 %, respectively.



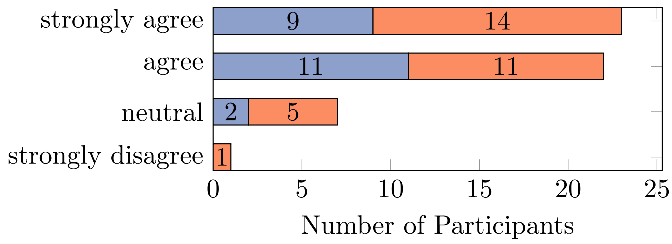
(a) *learned new things*



(b) *enjoyed discovering new things*



(c) *was curious*

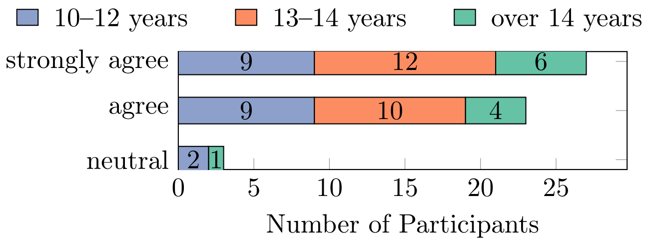


(d) *found that Scratch was a good way to learn how to program.*

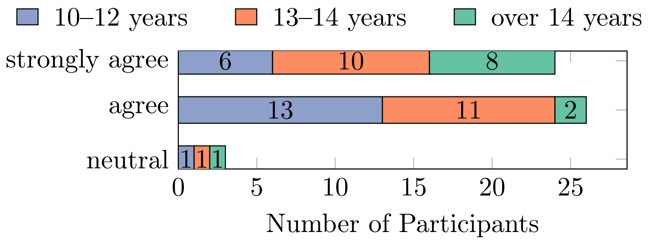
Figure 9. Participant responses to the respective statements of *During the GiC workshop, I . . .* .

4.4 Discussion of the Participants' Outlook of STEM

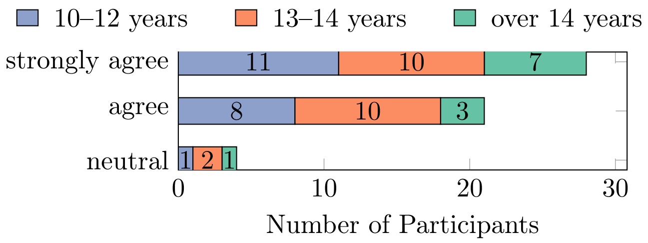
For the statements regarding the participants' attitudes towards STEM, 92 %–94 % of the girls agreed upon the three statements (Fig. 10(a)–10(c)). Especially interesting here is that girls in the eldest age group, over 14 years, were more likely to agree strongly with the statements regarding



(a) *Control and feedback cycles are present in many aspects of my daily life.*



(b) *Science and technology, in particular control engineering, can help understand and solve important problems.*



(c) *Learning about science and technology can help me to solve important problems of our time, e.g., medical treatment or protecting our environment.*

Figure 10. Participant responses to the indicated questions regarding their attitudes towards STEM.

the importance and prevalence of science, technology, and control in daily life.

4.5 Statistical Significance of the Results

From a statistical significance standpoint, due to the limited number of participants (a single vote is around 2 %) in the questionnaire, and that the participants resided mostly in Japan and Indonesia, participating in the Japanese and the English workshops, respectively, we find it hard to draw general conclusions about the efficacy of all of the workshops. However, due to the overwhelmingly positive results regarding how the girls experienced the workshop, we believe that we can make some conclusive remarks about how the workshop was generally perceived.

5. CONCLUSION

In general, most participants successfully grasped fundamental control engineering concepts following their engagement in the workshop. The overall feedback was highly positive, with only minor differences depending on whether participants had prior programming experience. Furthermore, the overall attitude towards STEM was notably favorable, particularly among older girls who attributed greater significance to the role of STEM in contributing to societal advancements.

We conclude that the GiC workshop is targeting the correct demographic in a way that is received positively by participants with and without prior programming experience. Generally, the workshop is successful in educating girls in control engineering and engaging girls in STEM which helps to improve the participants' understanding of the world around them.

6. SELECTION AND PARTICIPATION OF CHILDREN

Before the workshop, both the children and their parents were informed of the purpose of the workshop, the questionnaire, and the handling of data and confidentiality. Informed consent was obtained accordingly. All of the participants who participated in the English and Japanese workshops were given time at the end of the workshop to fill out the questionnaire.

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