# COMPUTATIONAL THINKING STUDY BY TECMUJER

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TECHNOVATION Girls Chile

MOTOROLA SOLUTIONS FOUNDATION

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# INTRODUCTION

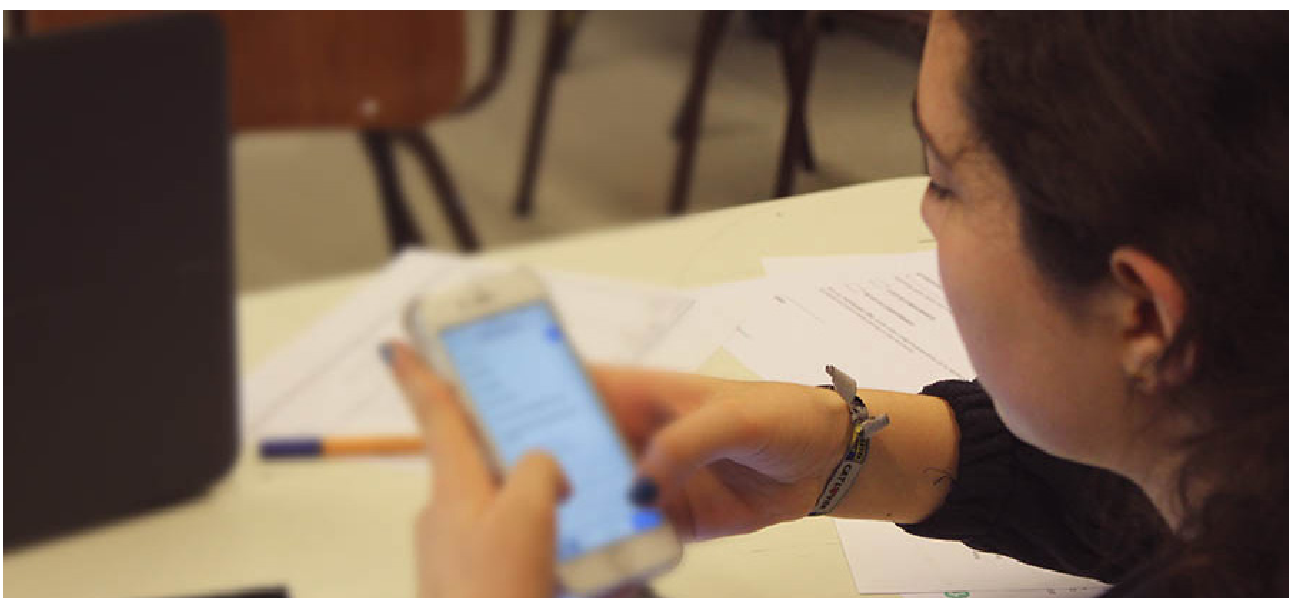
Globally, there has been growing support for programs that encourage students to code, as a way to develop their computational thinking and 21st century skills (see eg, [1, 4, 8-13, 16, 17, 19, 21, 23, 24, 26]). Evaluating these programs is challenging, as students are not only exposed to new concepts, but also work on developing new abilities and skills. It is also too early to analyze the long-term effects these programs have on students.

The Technovation Girls (TG) program, present in more than 110 countries, is a program where its curriculum does not focus solely on coding, but also includes topics in computer science, entrepreneurship, social problem solving, and business leadership. Generally organized as an after school club, female students work for 12 to 32 weeks in teams of 2 to 5 girls ages 10 to 18 to devise and prototype a mobile app that addresses one of the Sustainable Development Goals of the University. Teams have the chance to present their prototypes to national and international judges, and local winning teams advance to the Technovation Challenge, a grand finale held once a year. According to its website, "Students express an increased interest in technology and leadership after participating in our program, and 58% of our graduates enroll in more computer science courses after Technovation."

The chapter studied in this article has been active for the last 6 years in Chile, located in South America. This chapter has been participating in the TG program in its local context and at the end of 2019, it decided to try to run the TG program during school hours, within the framework of the Technology subject, taking advantage of the conceptual similarities of the Technology subject curriculum. applies project-based learning methodology and the TG program all of this rather than after school. This required several adaptations such as: extending the duration of the program to the school year, expanding the curriculum to better support students in vocational or technical vocational schools and allowing mixed teams (not participating in the international), most of them the schools here are coeducational.

Something important to comment on the installation of the program was the Covid-19 pandemic factor that struck in early 2020, an instance where schools had to quickly switch to online classes. Each school has at least one teacher who works with their students on the TG program during the year, and they are supported by a STEM professional paid by the local TG chapter called KAM.

Since one of the main products of the TG program is the prototype of the mobile application, we wanted to study whether the changes made in the TG program had an impact on the computational thinking skills of the students. As such, the following research question was posed: Does participating in the TG program have an impact on the computational thinking development of students? To answer this question, the experience in 3 secondary schools that offer vocational training was studied, with variable characteristics: located in different provinces of Chile. These three trade schools offer STEM-related career options. The students who participated in the study were all in the first half during 2020, but between the ages of 13 and 18.



# EDUCATIONAL ESTABLISHMENTS CHARACTERIZATION

## Instituto Superior de Comercio Francisco Araya Bennett de Valparaíso (INSUCO)

Establishment located in the city of Valparaíso, Valparaíso Region. Mixed institution of professional technical training that has the specialties of Administration mention logistics, Administration mention human resources, Accounting, Programming and Tourism services. Its students have a vulnerability rate of 94%. The Technovation Girls Chile program was implemented in a "Trained and accompanied" modality.

## Liceo Comercial de Desarrollo Temuco (LCD)

Establishment is located in the city of Temuco, La Araucanía Region. It is a mixed professional technical training institution in which its students can specialize in Administration, Accounting, Graphics and Programming. In addition, they have a dual specialization program in which students can train at the high school and in a company simultaneously. Its students have a vulnerability rate of 90%. The Technovation Girls Chile program was also implemented in a "Trained and accompanied" modality.

## Liceo Comercial Vate Vicente Huidobro (LCVVH)

Establishment located in the commune of San Ramón, Metropolitan Region. It is a mixed institution that offers professional technical education in the technical and commercial area. The students can specialize in Administration, Human Resources, Administration mention Logistics, Accounting and Computer Programming. The vulnerability index of its students is 92.16%. The Technovation Girls Chile program was implemented in a "Trained and accompanied" modality, that is, it began with a prior training of the Technology teachers and during the year, they were accompanied and supported in the implementation of the program.

In 2020, the data collection process was carried out in two instances, one entering in March at the beginning of the school year and another leaving it in November.

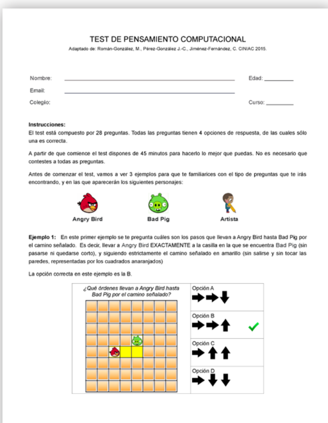
To evaluate the computational thinking skills of the students, the test developed by Román-González et al. [18], given that it has already been validated with a large population of Spanish speakers in an age range similar to our population. Students answered the test at the beginning of the TG program and then again at the end. It was found that, in general, there is a slight positive improvement in scores after completing the TG program, but with different trends by school, gender and age of the participants. High student confidence in their knowledge was also seen after the program, although there are moderate to large differences between expected and actual test scores. It ends with a discussion about the differences in the schools and how the TG program was implemented, which may explain these differences.

## RELATED WORK

There have been several proposals to assess the development of computational thinking in school-age children. Although computational thinking is considered a cognitive thinking process, several authors focus on evaluating the knowledge and skills acquired by the student [22]. As such, mastery of computational thinking skills relies on component analysis. This approach is convenient in practice, but does not necessarily capture aspects related to the learning process of students. These approaches are generally based on multiple-choice and true / false questions, as well as open-ended questions.

For example, Shell and Soh [20] used a set of 26 conceptual and problem-solving questions to assess the development of computational thinking skills. The conceptual questions were derived from a CS-1 course. Chen et al. [5] wanted to understand the effect that an activity with an educational robot had on students' computational thinking skills, so they developed 15 multiple-choice questions and 8 open-ended questions, which were contextualized in everyday situations and in specific scenarios of robot programming. Basawapatna et al. [2] wanted to study whether students detected certain basic patterns associated with computational thinking skills when developing video games or scientific simulations using a prototyping tool. They developed the Computational Thinking Patterns Questionnaire to assess participants' ability to recognize, understand, and transfer patterns to different non-video game contexts. Weintrop and Wilensky [25] developed the Commutative Assessment, a set of 28 multiple-choice questions, each of which shows a short program, equivalently written in block language (Snap) or text-based (JavaScript). The idea was to evaluate the transfer of concepts between text and block-based programming languages. Basu et al. [3] developed and validated a test to assess the computational thinking skills of students in grades 4-6. The test tasks are not coupled to specific programming representations, which puts the focus on computational thinking practices rather than programming structures, allowing the test to be used in different study plans and different programming languages. Several authors have used the Bebras Challenge tasks [6] to assess students' computational thinking skills, such as [7], [14] and [15].

In the framework of an exploratory analysis of the impact of the TG program, the computational thinking test developed by Román-González et al. [18], which assesses whether students can solve problems using sequences of instructions, iterations, conditionals, and variables. The test has 28 multiple-choice questions, where students must select the set of instructions that fulfill the required task. Instructions are presented using a block language, similar to Scratch or Snap. This test was chosen because it is publicly available, has been validated with students in grades 5-10, and the test is already in Spanish, which means it can be applied directly to participants in this study. The test authors validated it by calculating the correlation coefficients between the scores of the computational thinking test and two other instruments (Primary Mental Skills and the RP30 Problem Solving test), finding a high positive correlation between the scores of the thinking test. computational and problem-solving ability of students and small to moderate positive correlations for other mental abilities.



TEST DE PENSAMIENTO COMPUTACIONAL

Adaptado de: Román-González, M., Pérez-González J.-C., Jiménez-Fernández, C. CINIAC 2015.

Nombre: ______ Edad: ______

Email: ______

Colegio: Curso: ______

**Instrucciones:**

El test está compuesto por 28 preguntas. Todas las preguntas tienen 4 opciones de respuesta, de las cuales sólo una es correcta.

A partir de que comience el test dispones de 45 minutos para hacerlo lo mejor que puedas. No es necesario que contestes a todas as preguntas.

Antes de comenzar el test, vamos a ver 3 ejemplos para que te familiarices con el tipo de preguntas que te irás encontrando, y en las que aparecerán los siguientes personajes:

Angry Bird    Bad Pig    Artista

**Ejemplo 1:** En este primer ejemplo se te pregunta cuáles son los pasos que llevan a Angry Bird hasta Bad Pig por el camino señalado. Es decir, llevar a Angry Bird EXACTAMENTE a la casilla en la que se encuentra Bad Pig (sin pasarse ni quedarse corto), y siguiendo estrictamente el camino señalado en amarillo (sin salirse y sin tocar las paredes, representadas por los cuadrados anaranjados)

La opción correcta en este ejemplo es la B.

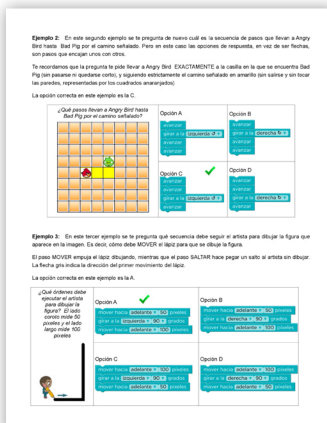
*¿Qué órdenes llevan a Angry Bird hasta Bad Pig por el camino señalado?*

Opción A

Opción B

Opción C

Opción D



**Ejemplo 2:** En este segundo ejemplo se te pregunta de nuevo cuál es la secuencia de pasos que llevan a Angry Bird hasta Bad Pig por el camino señalado. Pero en este caso las opciones de respuesta, en vez de ser flechas, son pasos que encajan unos con otros.

Te recordamos que la pregunta te pide llevar a Angry Bird EXACTAMENTE a la casilla en la que se encuentra Bad Pig (sin pasarse ni quedarse corto), y siguiendo estrictamente el camino señalado en amarillo (sin salirse y sin tocar las paredes, representadas por los cuadrados anaranjados)

La opción correcta en este ejemplo es la C.

*¿Qué pasos llevan a Angry Bird hasta Bad Pig por el camino señalado?*

Opción A: avanzar / girar a la izquierda / avanzar / avanzar

Opción B: avanzar / girar a la derecha / avanzar / avanzar

Opción C: avanzar / avanzar / girar a la izquierda / avanzar

Opción D: avanzar / avanzar / girar a la derecha / avanzar

**Ejemplo 3:** En este tercer ejemplo se te pregunta qué secuencia debe seguir el artista para dibujar la figura que aparece en la imagen. Es decir, cómo debe MOVER el lápiz para que se dibuje la figura.

El paso MOVER empuja el lápiz dibujando, mientras que el paso SALTAR hace pegar un salto al artista sin dibujar. La flecha gris indica la dirección del primer movimiento del lápiz.

La opción correcta en este ejemplo es la A.

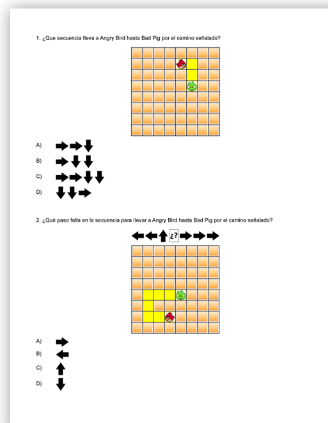
*¿Qué órdenes debe ejecutar el artista para dibujar la figura? El lado coroto mide 50 pixeles y el lado largo mide 100 pixeles*

Opción A: mover hacia adelante 50 píxeles / girar a la izquierda 90 grados / mover hacia adelante 100 píxeles

Opción B: mover hacia adelante 50 píxeles / girar a la derecha 90 grados / mover hacia adelante 100 píxeles

Opción C: mover hacia adelante 100 píxeles / girar a la izquierda 90 grados / mover hacia adelante 50 píxeles

Opción D: mover hacia adelante 100 píxeles / girar a la derecha 90 grados / mover hacia adelante 50 píxeles



1. ¿Que secuencia lleva a Angry Bird hasta Bad Pig por el camino señalado?

A)

B)

C)

D)

2. ¿Qué paso falta en la secuencia para llevar a Angry Bird hasta Bad Pig por el camino señalado?

¿?

A)

B)

C)

D)

Table 1 lists the participating high schools, the total number of students per school, as well as the average class size ("Average Class"). The column "Teacher" indicates how many teachers participated in the TG program at each school, as well as their gender (M = Male, F = Female). Larger schools have more than one class per grade, and the "Cohort" column indicates the estimated number of 9th grade students who participated in the TG program. Finally, the columns "Entry" and "Exit" indicate how many students completed the computational thinking test, before and after completing the TG program, respectively (participation was voluntary). In the case of the exit test, the number of female students is also indicated in parentheses, since this information was available.

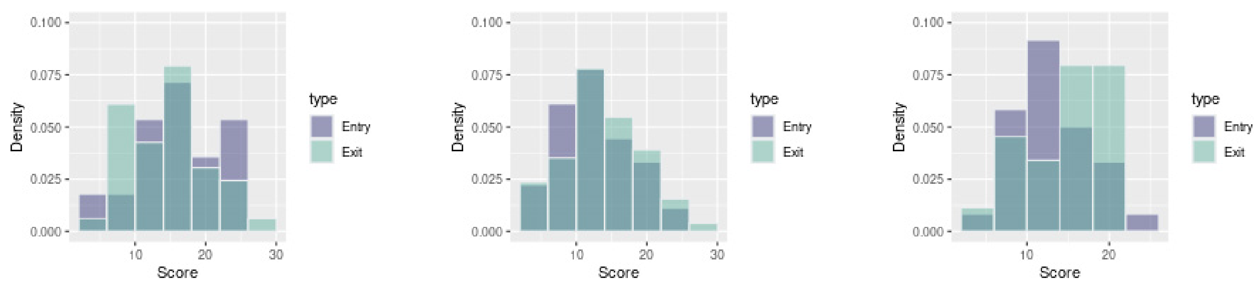
| Escuelas | Estudiantes | Maestro | Cohorte | Entrada | Salida (mujeres) |
|---|---|---|---|---|---|
| INSUCO | 850 | 1 F | 200 | 14 | 41 (27) |
| LCD | 230 | 1 F | 80 | 45 | 63 (31) |
| LCVVH | 340 | 1 F | 80 | 30 | 22 (10) |
| | | | | **Total** | **126 (68)** |

**Table 1: Participating establishments**

All three establishments are technical schools, which means that students graduate with a degree, such as an electrician, programmer, assistant accountant, etc. Participating teachers completed a training course during January 2020 and conducted the TG program during the school year (March - December 2020). The TG program was implemented during Technology class. The LCD and LCVVH schools had offered the TG program as an after-school activity during 2019, but like the rest of the schools, they offered it during school hours for the first time in 2020.

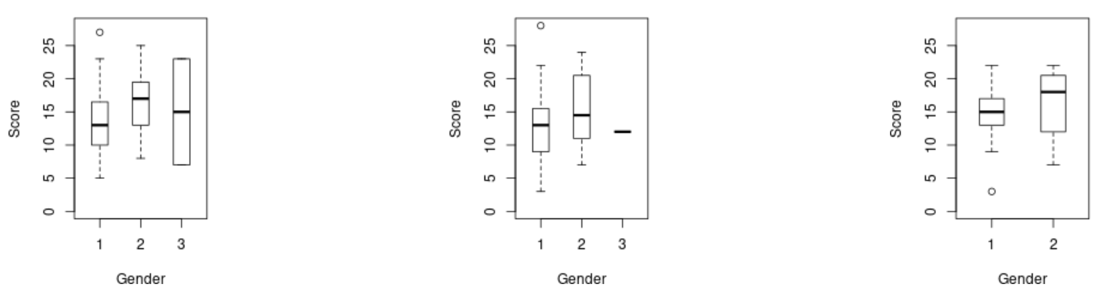
The schools are located in cities that are provincial capitals. Despite the fact that only 9th grade students were served during 2020, the ages of the students ranged from 13 and age 18, as these vocational schools also host students who dropped out of regular high schools. For these schools, this program is probably their first approach to computer science.

Figure 1 shows the distribution of scores for the entrance and exit tests by school, using density plots. LCD and LCVVH schools are seen to show some improvement in exit scores, compared to entry scores. At INSUCO school, a shift to the left is seen in exit scores, meaning that students on average scored lower on the exit test. Therefore, it is not clear whether these scores represent an improvement in students' CT skills.




(a) INSUCO (b) LCD (c) LCVVH

**Figure 1: Score Density Plots - Entry and Exit Tests**

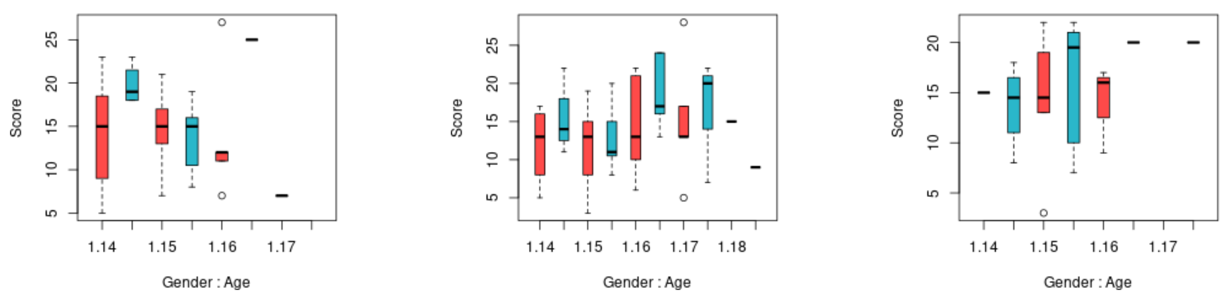



(a) INSUCO (b) LCD (c) LCVVH

**Figure 2: Exit test scores: gender distribution**

As the students indicated their gender during the exit test, Figure 2 shows the distribution of scores by gender. Students can be female (1), male (2), or non-binary / no response (3). Here it can be seen that the interquartile range for women in the LCD and LCVVH establishments is lower than that of men, which means that women present less variability in the middle half of the scores.

The question is whether the scores are similarly distributed by grouping students by gender. The graphs in Figure 3 show the distribution of scores by school, taking into account sex and age.

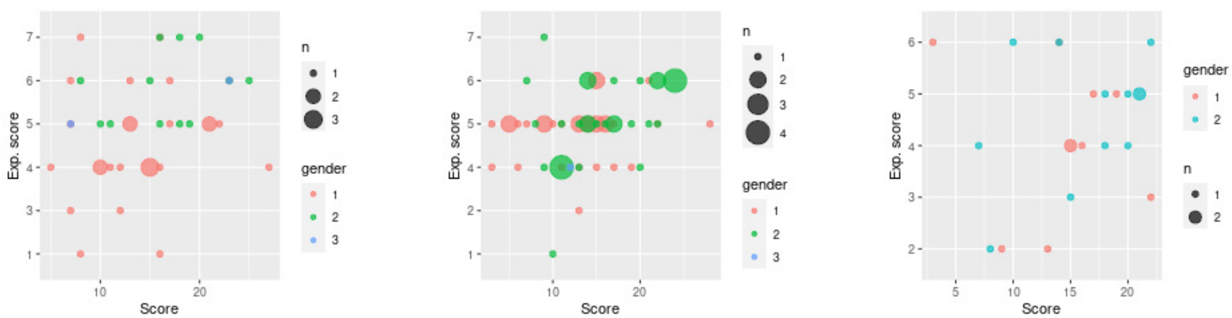



(a) INSUCO (b) LCD (c) LCVVH

**Figure 3: Exit test scores: distribution by gender and age**

Since few participants chose non-binary / no response, these participants were withdrawn from this analysis. The labels on the X-axis indicate the corresponding combination (Sex: Age) for each bar (for example, "1.14" means 14-year-old female participants). The bars were also colored by gender to facilitate reading (red = women, blue = men). In INSUCO, it is seen that the median changes by gender for the 15-year-old participants, which is also observed in LCD. Finally, in LCVVH it is seen that the median remains stable or improves, regardless of sex.

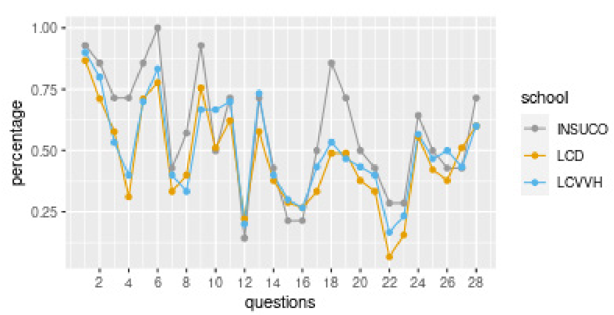
We also wanted to contrast the scores obtained by the students with the scores they thought they would obtain in the exit test. The bubble charts in Figure 4 show this relationship, where the expected score is on the Y axis (1 = very bad, 7 = very good) and the test score is on the X axis (0 - 28 points). The size of the bubble indicates how many students have the same combination (test score, expected score) and the color of the bubble indicates gender. Bubbles near the main diagonal mean that a participant scored similar to her expectations. The bubbles on the diagonal are participants who believed they would do better on the test than they actually did, and below the diagonal means they did better than expected. It is seen that, in general, the students were confident in their answers, with LCVVH students being the most pessimistic about their scores (regardless of gender). It is also seen that in INSUCO men were more optimistic about their performance than women.



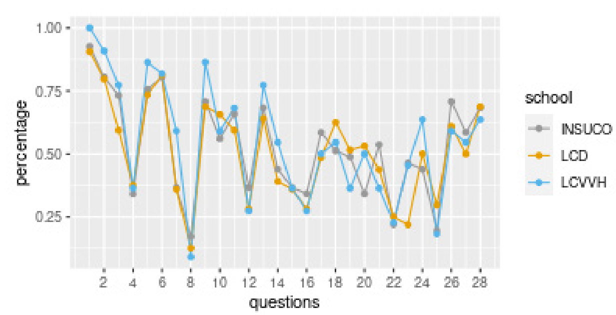

(a) INSUCO (b) LCD (c) LCVVH

**Figure 4: Expected score versus actual score, by gender**

Finally, the percentage of correct answers per question and school, before and after completing the TG program, was analyzed. The left graph in Figure 5 shows the input test percentages, the right graph shows the output test data. Here it can be seen that both curves are similar, although there is less variability in the exit test, especially between questions 15 and 23. There is also a slight improvement in the percentage of correct answers for questions 12, 22 and 23. Without However, it is also seen that questions such as 8 and 25 now have a higher incorrect response rate, in all schools, so that an activity in the TG program may be causing some confusion among the participants, although it cannot be rule out that there may be problems with the wording of the question that may be causing this effect.




(a) Entrance




(b) Exit

**Figure 5: Percentage of correct answers per question, by school**

## DISCUSSION

A slight improvement was seen in exit test scores, which is promising given that TG's primary focus is product ideation, launch, and prototyping, and not programming. Students use a low-code platform (Thunkable) to develop mobile applications, which still requires them to think about the logical and business processes they need to implement to bring their ideas to fruition. Students should also work on communicating technical aspects of their work, such as design and implementation decisions.

The teams could be mixed gender, but it was found that male students generally performed better than female students on the exit test, thus female students may benefit from additional female-only activities before / during the execution of the TG program in the school.

Adjusting to online school during the Covid-19 pandemic was also a challenge. In South America, the first cases of Covid-19 appeared in March 2020, and schools closed in April due to fears of contagion. Schools were quick to transition to online teaching as the number of infections increased and the blanket lockdown extended. Students had to adapt to the devices their families already had, sometimes sharing the same computer with several siblings in order to attend class. This made working online challenging as both students and teachers had to adapt to new tools and dynamics, without much time to prepare. Some schools also had problems with attendance, such as LCD and LCVVH, where only 60% of students showed up for online classes, but only 20% were constant, the rest varied from week to week.

It was also seen that the TG program had different effects on the students, depending on the conditions of the school, such as the age of the participants and the distribution by gender. The schools analyzed are of different sizes: INSUCO is the largest school in the 2020 cohort, while LCD and LCVVH are smaller. All three schools had a teacher in charge of the TG program, and there was near parity between male and female students on the test of exit. However, it is seen that the first grade students on average obtained lower scores than the male students, but this is not consistent by age. For example, both INSUCO and LCD have classes of similar size (20-23 students), and here it is seen that 15-year-old students perform similarly or better than their male peers. On the other hand, LCVVH has 28 students per classroom on average, and male students are seen to outperform female students regardless of age.

Although the TG program had originally been planned to be held in person, it had to be improvised due to the Covid-19 pandemic. These results are believed to show that the changes made to adapt the program to the Chilean context were reasonable and have had a positive effect on participating students. A focus group was also held at the end of the school year, where most of the participants indicated that they now understand that creating an application is much more than programming, it is necessary to identify a real problem and then understand how (and if) technology can be done. use to solve certain aspects of the problem.

None of the 2020 cohort met TG's international challenge, as the barriers to entry for trade school students in a non-English speaking country are simply too high. However, both teachers and students were generally satisfied with the experience. Two to five teams per school completed their prototypes and successfully presented them to a panel of local judges. Overall, the participants were confident in what they had learned in the TG program, as evidenced by the overconfidence seen in the bubble charts in Figure 4, as they were unaware that the test only assessed their skills in training. computational thinking, and not the whole of what they learned as part of the TG program.

## CONCLUSIONS

It was found that the TG program can be carried out during school hours in coeducational secondary schools offering vocational training. This involved making the TG program part of a required class, expanding the existing TG curriculum, adapting activities and dynamics to online teaching, and relaxing TG language requirements. The TG program was also found to have a slight and positive effect on the CT skills of the 2020 cohort, although these effects depend on gender, age, and school conditions. It is believed that female students can benefit from female-only activities before and during the TG program, in order to increase their exposure to technology, in order to level the playing field with respect to their male peers.

This initial and exploratory shot that seeks to measure the impact of the TG program on girls and young people shows us a way to continue exploring the impact of the program, as well as determining the impact that the program can have, in terms of knowledge acquisition in programming, It is believed that we must continue studying the students, perhaps with a tool that can see in a more comprehensive way the acquisition of knowledge around programming.

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