Report

Intellectual Output 5:

Blueprint on the successful use of inquiry in teaching ICT

TIWI
Teaching ICT with Inquiry

European Schoolnet

ABOUT THE TIWI TEACHING ICT WITH INQUIRY PROJECT

The Teaching ICT with Inquiry (TIWI) project provided teachers with tools and skills to enable them, with the use of the inquiry-based approach, to teach coding – the digital language used by ICT tools and STEM subjects. TIWI helped upper primary and secondary educators to: gain new skills and be in a position to teach coding efficiently to their students, with the help of examples from STEM subjects; become comfortable in using the inquiry-based approach and interactive tools in their teaching for learning by doing; implement inquiry-based activities in classrooms all over Europe.

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Table of Contents

List of Tables

List of Figures

Introduction

The present publication aims to provide educators and other educational stakeholders with evidence and concrete examples of the suitability and usefulness of teaching ICT through a pedagogical approach based on investigation. In addition, it offers guidance and recommendations for future applications of Inquiry-based learning scenarios (IBLS) to teach ICT.

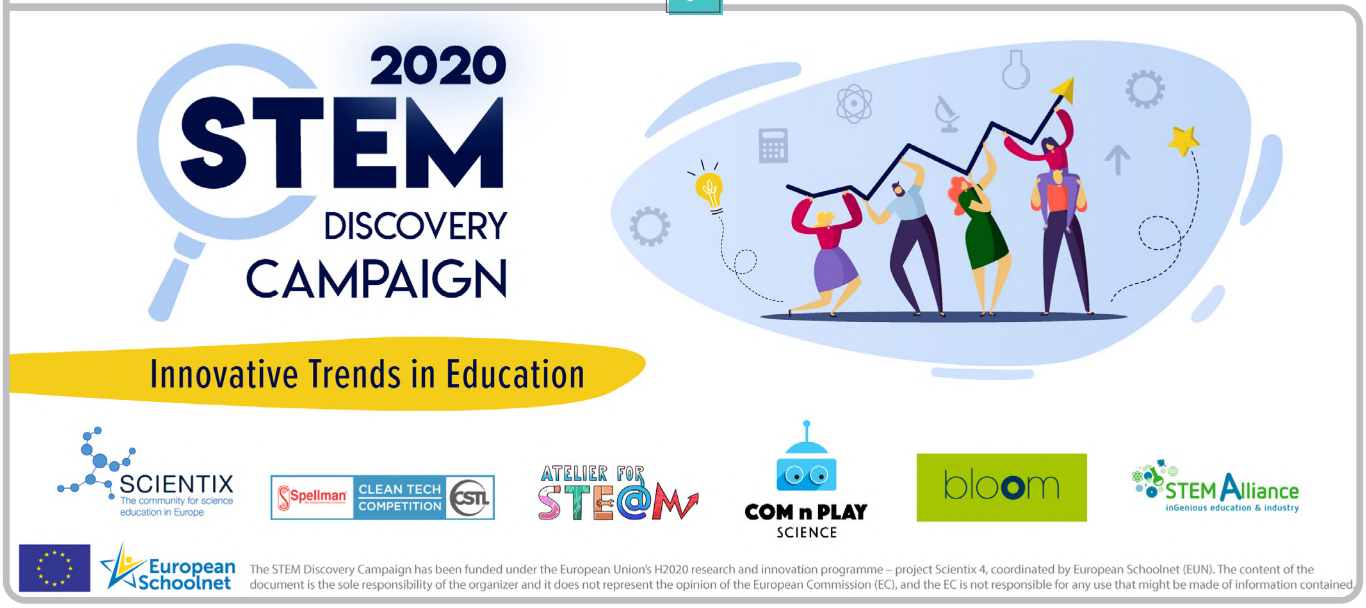
This blueprint is divided into four main sections. At first, the rational, methodology and outcomes of a surveys conducted with the help of a group of focus teachers are presented. Carried out across 4 European Union Member States – Cyprus, France, Lithuania, and Spain – this study empirically tested the impact of the (Inquiry-based) proposed pedagogical method to teach and learn ICT.

Secondly, five examples of successful implementation of Inquiry-based learning scenarios are presented i.e. the winners of the European competition organised within the context of Intellectual Output 2, which was carried out in connection with the 2020 STEM[1] Discovery Campaign (SDC20).

Then, the main findings gathered from the survey carried out as well as the implementation stories are shown. Finally, a set of recommendations to educational authorities and policy makers is formulated by combining the findings of the survey and the lessons learnt via the case-studies. These recommendations aim at facilitating the use of Inquiry in teaching ICT and intend to maximise the exploitation of the advantages of such a method.

1 Science, Technology, Engineering and Mathematics.

http://scientix.eu/events/campaigns/sdc20



Research design and methodology

Two self-assessment questionnaires have been developed in the frame of TIWI for two target groups: teachers and students. Scales with closed items already presented in the scientific literature as well as scales developed by the Research in Science and Technology Education Group, University of Cyprus (UCY) were used. All scales were pilot tested with 128 students in 20 classes and 46 teachers in Cyprus, France, Spain, and Lithuania. With the results of the pilot test and after receiving and elaborating upon the feedback of all partners in the consortium, the final form of the instruments was developed. These were first formulated in English and then translated in Lithuanian, Spanish, French, and Greek.

STRUCTURE AND ADMINISTRATION

The instruments were administered online to individual respondents via SurveyMonkey before and after the educational interventions of TIWI in Lithuania, Spain, France and Cyprus. Several scales were offered to both target groups, which could be pre-selected in the online form of the instruments.

In this regard, the instruments can be administered in a modular form, where each respondent is able to compile a personalised version of the instrument, based on their individual needs. The online version of the instruments also included items on basic socio-demographic characteristics and prior experience of the respondents, as well as work environment items for teachers. In addition, some core terms have been defined to provide background information to respondents for the completion of the scales.

Table 1 and Table 2 present the structure of the instruments for teachers and students, respectively. All items for all scales are presented in Appendices 1 for the teacher instrument and 2 for the student instrument.

Table 1. Scales in the self-assessment instrument for teachers

Scale	Source	Number of items
Background characteristics	Newly developed	2
Prior experience	Newly developed	5
Work environment	Newly developed	7
Instructional design	Newly developed	8
Responsive instruction	Newly developed	8
Formative assessment	Newly developed	8
Computational thinking	Bean et al., 2015	8
TPACK Questionnaire	Schmidt et al., 2009	38
Inquiry	Enochs & Riggs, 1990	8

Table 2. Scales in the self-assessment instrument for students

Scale	Source	Number of items
Background characteristics	Newly developed	3
Prior experience	Newly developed	5
Inquiry skills	Burns et al., 1985	
Identifying Variables		12
Identifying and Stating Hypotheses		9
Operationally Defining		6
Designing Investigations		3
Graphing and Interpreting		6
Student attitudes	Kind et al., 2007	
Learning science in school		6
Science outside of school		6
Future participation in science		4
Importance of science		3
Programming	Kong et al., 2018	15
21st century skills	Unfried et al., 2015	11

PILOT STUDY

A pilot study was conducted in the first half of 2019 with a sample of 128 students and 60 teachers in each country (Lithuania, Spain, France and Cyprus). Data analysis was taken over by the Research in Science and Technology Education Group, UCY. We were able to verify acceptable reliability and validity indices for all pre-specified scales. The three scales developed by the Research in Science and Technology Education Group, UCY, for the teacher questionnaire also had acceptable outcomes in terms of validity and reliability, as presented in Table 3.

Table 3. Validity and reliability indices for the three newly developed scales

Scale	Validity indices (Factor analysis)		Reliability indices (Reliability analysis)
	Kaiser-Meyer-Olkin Measure of Sampling Adequacy	Component matrix	Cronbach's alpha
Instructional design	0.86	Only one component was extracted	0.91
Responsive instruction	0.86	Only one component was extracted	0.89
Formative assessment	0.88	Only one component was extracted	0.92

Note: The Kaiser-Meyer-Olkin Measure of Sampling Adequacy should be higher than 0.50, while all items in a scale should load on one factor (component); Cronbach's alpha values should be higher than 0.70.

FULL-SCALE ADMINISTRATION OF THE INSTRUMENTS

Both instruments were administered online to all teachers (primary and secondary school teachers) and students (primary and secondary school students) who were involved in the implementations of Inquiry Learning Spaces developed within the frame of the TIWI project in Cyprus, France, Lithuania, and Spain. The instruments were used in a pre-post test arrangement and were completed by teachers and students before the implementations begun and just after they were concluded. We received 1 094 student questionnaires before the implementations, which were reduced to 938 after deleting cases with incomplete data. After the implementations, we received 814 student questionnaires, which dropped to 608 after omitting cases with incomplete data. Regarding teachers, out of 172 respondents prior to implementations, 145 were retained with a full series of data. After the conclusion of the implementations we gathered 110 teacher questionnaires, 100 of which had no gaps in their completion. Using a coding scheme in the teachers' questionnaire, we were able to identify 50 teachers who completed the instrument both before and after the implementations. This is the sample where data analysis will focus on for the teachers' questionnaire.

Students' questionnaire

Sample characteristics: Girls comprised 53.5% of the total student sample in the pre-test, and 51.5% of the post-test; mean age equalled to 13.00 years before and 12.57 years after the implementations, min = 9 years, max = 18.

Prior experience (pre-test): About two-thirds of the student sample had prior learning experience with Inquiry-based learning (63.5%) and programming (66.8%) in school, while a substantial majority had worked with computers in STEM-related school classes (73.8%). More than half of the student sample had analogous experience working with computers outside school (51.6%), while only 13.3% had used the Go-Lab ecosystem in the past.

Comparison of student responses before and after the implementation: Data analysis showed that the only scale with statistically significant increase after the implementations was programming self-efficacy (Table 4). This effect needs to be discussed in accordance with the programming component in the design of the Inquiry Learning Spaces which were developed and implemented in the frame of the TIWI project.

Table 4. Responses across scales in the students' questionnaire before and after the implementations

	Before the implementations (N = 938)	After the implementations (N = 608)	Mann-Whitney Test Statistic (Z)
Identifying and Stating Hypotheses	0.35	0.35	-1.33ns
Future participation in science	0.59	0.60	-0.34ns
Meaningfulness of programming	0.66	0.68	-1.61ns
Impact of programming	0.66	0.68	-1.68ns
Creative self-efficacy in programming	0.71	0.71	-0.45ns
Programming self-efficacy	0.65	0.68	-2.81**

Note: Values presented refer to aggregate scores of student responses for each scale recalculated to range between 0 and 1 (see Appendix 1 for a detailed presentation of all items in all scales); ns = non-significant, * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

Heterogeneity in the student sample after the implementations: the student sample after the implementations of the Inquiry Learning Spaces was distinguished into two different clusters based on student responses in the scales of the instrument (Table 5). Student Cluster 1 (50.16%) presented increased average responses across all scales, as compared to the responses of Student Cluster 2 (49.84%), which proved highly significant in the statistical test which was conducted. This finding implies that the student sample is evenly split in a student cluster of consistently higher ability and attitudes (Student Cluster 1), and another cluster of consistently lower ability and attitudes (Student Cluster 2).

Table 5. Student clusters after the implementations

	Student Cluster 1 (50.16% of the student sample)	Student Cluster 2 (49.84% of the student sample)	Analysis of Variance Statistic (F)
Identifying and Stating Hypotheses	0.43	0.26	87.48***
Future participation in science	0.71	0.48	226.27***
Meaningfulness of programming	0.83	0.53	584.12***
Impact of programming	0.82	0.54	507.17***
Creative self-efficacy in programming	0.84	0.59	433.24***
Programming self-efficacy	0.80	0.56	356.26***

Note: N = 608; ns = non-significant, * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

Further analysis showed that students in Cluster 1, as compared to students in Cluster 2, had more prior learning experience with Inquiry-based learning (Likelihood ratio Chi-Square = 13.86, $p < 0.001$), and programming (Likelihood ratio Chi-Square = 7.08, $p < 0.01$) in school, they had worked more with computers in STEM-related classes in their classrooms (Likelihood ratio Chi-Square = 38.75, $p < 0.001$) and outside their schools (Likelihood ratio Chi-Square = 15.23, $p < 0.001$), and they had used more the Go-Lab ecosystem in the past (Likelihood ratio Chi-Square = 12.97, $p < 0.001$).

Teachers' questionnaire

Sample characteristics: Females predominated in the teacher sample (76.0%). Most teachers (46.0%) were aged between 36 and 45 years, followed by the age cohort of 46-55 years (22.0%), the age cohorts of >55 years (12.0%) and 26-35 years (12.0%), and finally, the age cohort of ≤25 years (8.0%).

Prior experience: With regard to years of teaching experience, 22.0% of teachers had 5 years of teaching experience or less, 18.0% had 6-10 years, 16.0% had 11-15 years, 12.0% had 16-20 years, and 32.0% had more than 20 years of teaching experience. More than half of the sample (52.0%) had studied STEM-related postgraduate studies, while a substantial percentage of 78.0% had followed STEM-related professional development. About two-thirds (64.0%) had STEM-related experience with computer-supported learning environments, and 62.0% had used the Go-Lab ecosystem in the past.

Work environment: Teachers' work environment was mainly characterized by school administrations supporting the integration of digital technologies in the classroom (average response = 4.10 along a 5-point Likert scale), while teachers stated that their students had good access to digital devices connected to the Internet at home (average response = 4.10 along a 5-point Likert scale). Lower average values but still higher than the mid-point of the Likert scale were recorded for schools' internet connection being reliable and fast (average response = 3.82), for curricula facilitating and supporting the use of digital technologies in the classroom (average response = 3.74), students having access to digital devices (laptops, tablets, smartphones) in the classroom (average response = 3.70), teachers' colleagues using digital technologies in the classroom (average response = 3.60), and Interactive Whiteboards being available in the classroom (average response = 3.54).

Comparison of teacher responses before and after the implementation: Table 6 presents the average responses of teachers across scales (5-point Likert scales, min = 1; max = 5) in the teachers' questionnaire before and after the implementations.

Although there was an improvement after the implementations for all scales, this improvement was statistically significant in the case of computational thinking only ($Z = -2.35$, $p < 0.05$). Correlational analysis showed that improvement in one scale was accompanied by improvement in the rest of the scales (Table 7). The research results are explained in detail under the section "Findings".

Table 6. Responses across scales in the teachers' questionnaire before and after the implementations

	Before the implementations (N = 50)	After the implementations (N = 50)	Wilcoxon Test Statistic (Z)
Formative assessment in computer-supported learning environments	3.65	3.77	-1.97^{ns}
Computational thinking	3.43	3.63	-2.35^{*}
Efficacy in teaching Inquiry-based STEM	3.43	3.60	-1.92^{ns}

Note: Values presented refer to average responses for each 5-point Likert scale (min = 1, max = 5; see Appendix 2 for a detailed presented of all items in all scales); ns = non-significant, * p < 0.05 ** p < 0.01 *** p < 0.001.

Table 7. Spearman's rho correlation coefficients for improvement in average values across scales in the teachers' questionnaire

	Computational thinking	Efficacy in teaching Inquiry-based STEM
Formative assessment in computer-supported learning environments	0.46^{***}	0.50^{***}
Computational thinking		0.45^{***}

Note: Correlational analysis was conducted after subtracting post-test values from pre-test values in teacher responses; ns = non-significant, * p < 0.05 ** p < 0.01 *** p < 0.001.

The five case studies presented here below provide further evidence of the relevance and suitability of Inquiry-based learning to teach coding and ICT for STEM. They complement the results of the survey, offer an in-depth insight into this pedagogical approach and allow for a multidimensional assessment of its value.

All case studies were selected among the pool of 14 schools that successfully participated to the TIWI competition, which took place between February and June 2020 in the framework of the 2020 STEM Discovery Campaign (SDC20).

The competition called for teachers to share their experience and best practices of implementation of Inquiry-based science teaching in ICT and STEM subjects. It invited teachers to create an implementation story i.e. a transversal report describing the processes and impact of introducing ICT with Inquiry method using collaborative spaces as personal learning environments for students and Go-Lab as a teaching methodology.

The stories collected included classroom as well as online activities carried out between the 1st of February and the 30th of April 2020. Indeed, due to the sudden outbreak of the Covid-19 pandemic and the measures that were put in place in most countries to mitigate its effects, participants were allowed to conduct Inquiry-based learning activities both face to face and online.

Evidence of implementation was mostly gathered through Graasp, a social learning platform where links to the activities designed and carried out were posted together with any other relevant material, including pictures, social media posts, etc.

https://graasp.eu/

THE WATER CYCLE: SCIENCE AND CODING

Aleksej Peržu, one of the two Lithuanian teachers within the pool of winners of the competition, invited 12-year-old students of the "Vilniaus Aleksandro Puškino gimnazija" to think about the importance of water for human life and in nature. In addition, he introduced his students to the notion of water cycle using Go-Lab as well as Scratch.

A total of 26 students took part to the activity, which brought together STEM subjects (i.e. water and water cycle in nature) and coding as a water cycle animation was created with Scratch and presented to the students. The activity was implemented in a classroom environment and lasted one hour – it took place on the 10th of February 2020.

Aleksej's admitted that students of 12 years of age are perhaps too young to code independently with Scratch. Indeed, during the classroom implementation of the learning activity he had to personally assist many students to help them code correctly and achieve the goal established. Nonetheless, presented with the water cycle animation students were surprised and very eager to understand how it was created via coding.

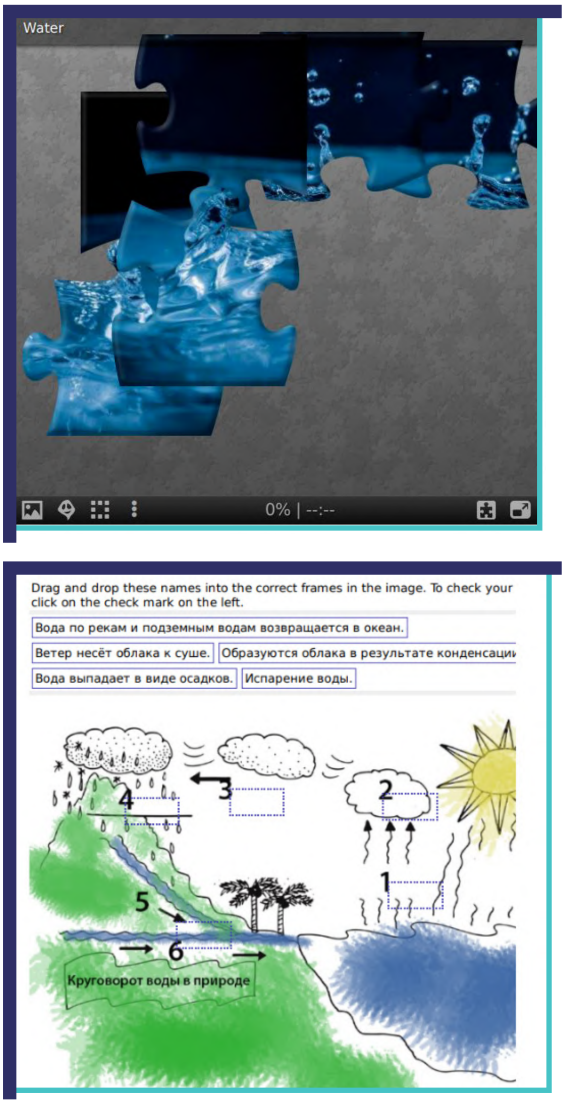


Figure 1. Evidence of IBLS implementation in Lithuania – The Water Cycle

Students' curiosity towards coding was very helpful and greatly helped Aleksej feed the discussion about the importance of coding in different jobs nowadays. Indeed, within this context he could effectively show that coding is not only an activity for programmers, but it is relevant in many fields of work, including science, and can stimulate students' creativity.

MUSIC AND STEM

Starting from the idea that the link between music and mathematics dates back to the ancient times, Mario Di Fonza, of the "Istituto Statale per l'Istruzione Superiore", Pomigliano d'Arco (NA), Italy, proposed students to associate those two topics and study their inner connection.

Accordingly, 20 students of 16 years of age investigated the mathematics which lay behind music composition as well as coding. The activity was carried out over 4 learning sessions, which took place between the 10th of February and the 26th of April 2020.

Activities were carried out both in a classroom environment and online, implementing the Inquiry-based learning scenario that Mario designed for this purpose. Students used Scratch to programme music and Graasp as well as Go-lab to carry on and share their Learning experiences.

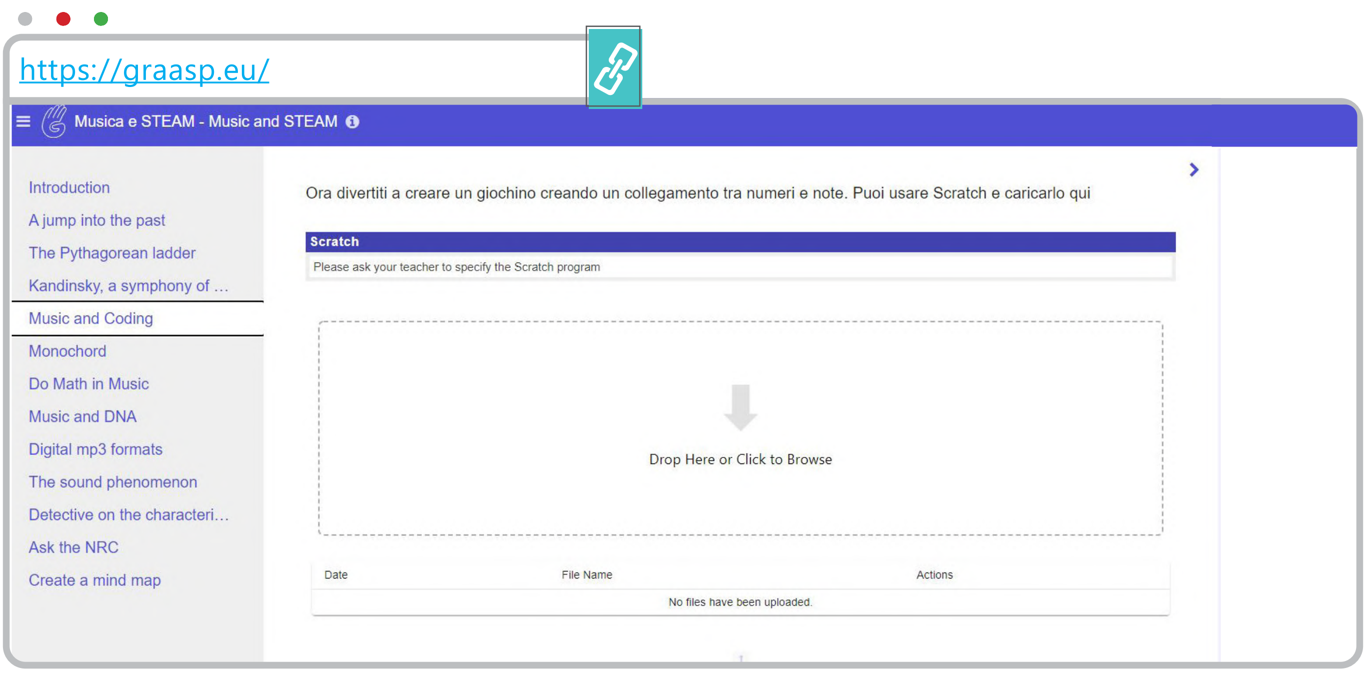


Figure 2. Evidence of IBLS implementation in Italy – Music and STEAM

As the use of digital tools is common practice in Mario's school, students did not have problems in implementing the Learning scenario designed, coding notes and music. In fact, they enjoyed carrying out all the activities and fed the learning scenario with material found on several websites.

According to Mario, students showed great interest in the topic tackled as well as the tools employed, which they could use independently. Combining mathematical theory with real life experience highly stimulated students' interest, facilitating learning and comprehension: studying turned into both an exploration and a discovery of mathematical concepts.

In the light of his experience, Mario suggests that it is possible to propose an elementary approach to mathematical modelling since high school, especially thanks to the use of new technologies. As today's teenagers are native digital citizens, it is easy for them to use digital tools to learn. Hence, they should be given more often the opportunity to learn employing this kind of tools.

Inquiry-based learning helps students appreciate the potential of the mathematical language, provides them with a true awareness of the theory behind programming and supports the construction of a wealth of knowledge which will help them find jobs in the future.

Although it was created by Mario, the Inquiry-based learning scenario on Music and STEAM was also used by two other teachers at the same school – i.e. Sabrina Nappi and Rosanna Busiello – who successfully implemented it in their classes as well.

PROGRAMMERS AND COMPUTER GAMES

Do you like computer games? Who do you think creates them? What knowledge do programmers need to have? Would you like to become a programmer?

Starting from those questions Lidia Ristea, of the I.A. Bassarabescu Secondary School of Ploiesti, Romania, explored with 13-year old students the connection between programming and computer games, introducing them to the profession of game programmer.

All activities, which were based on a self-designed Inquiry-based learning scenario, took place online due to the outbreak of the Covid-19 pandemic. Graasp and Go-Lab were used to collect learning material and carry out exercises. A total of 24 students took part to the distance learning experience, which was conducted on the 23rd and 24th of April 2020 and was also shared with 5 additional teachers.

Within the Learning scenario, several videos were used to explain what a programmer does, what the skills required within this profession are and what the job involves. These videos, which caught students' attention and kept them engaged with the topic, presented students with the fact that to become a successful game developer a lot of hard work is needed.

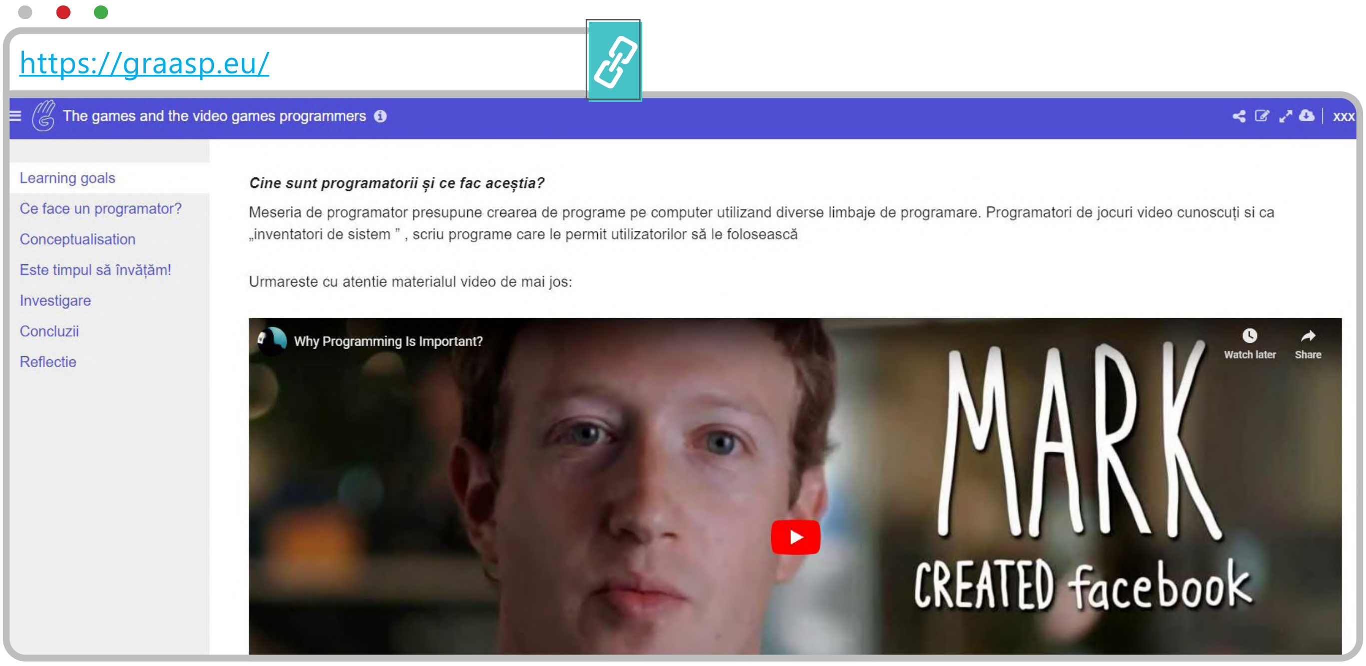


Figure 3. Evidence of remote IBLS implementation in Romania – Programmers and Computer Games

The topic chosen – i.e. programmers and computer games – was selected to make students aware of the ever-growing importance of the digital industry in the present society. In addition, it tapped in their existing digital skills and provided information to develop them further.

The Inquiry-based learning scenario designed promoted students' exploration and investigation of the topic under analysis. It stimulated students' creative and inventive spirit and invited them to put ideas into practice by presenting real life career models.

According to Lidia, the Inquiry-based approach made her work easier and had a positive impact on her teaching. It led the way to the use of Go-Lab and Graasp, through which she could easily track students' activities on real time and guide them if needed.

Although almost all students were familiar with the technology required, some needed personalised assistance. In addition, not everyone was able to run the labs and applications included in the Learning scenario at the same time due to slow internet connectivity. If problems were related to the lack of a suitable software or hardware, mobile phones would be used instead.

https://graasp.eu/

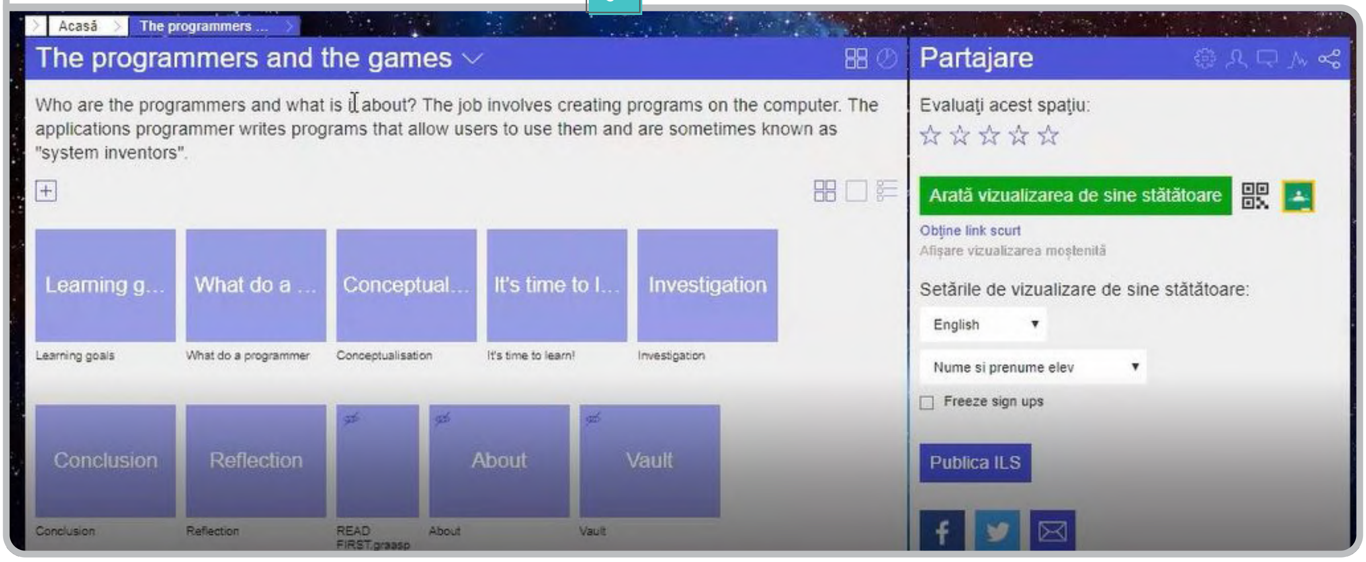


Figure 4. Evidence of remote IBLS implementation in Romania – Programmers and Computer Games

The Inquiry-based learning scenario created was designed paying special attention to students' perceived interest in the topic chosen as well as to its relevance for the current job market. During its implementation, the pedagogical strategy adopted consisted in fostering students believe that they are capable to succeed in whatever they undertake. Accordingly, positive feedbacks were given to support students' participation to and engagement in the learning scenario.

Lidia admitted that she had difficulties in creating Inquiry-based learning scenarios in the past, as she did not know how to connect different disciplines over one topic. However, participating to dedicated training sessions, workshops and summer schools she has gained the required knowledge and experience and is now confident at creating IBLSs.

In Lidia's experience nowadays most teachers have sufficient digital skills to introduce ICT topics in their classes. However, due to curriculum overload they do not have the time to use online applications and platforms in the classroom. Nonetheless, she recognises the importance of participating in online and face-to-face training courses to learn about new technologies and enhance their use in the classroom.

PHYSICS ON THE ROAD

According to Rigonda Skorulskiene – Kaunas Jesuit High School, Lithuania – most students do not find classical mechanics very interesting. On the contrary, they perceive it as a difficult and problematic topic.

For this reason Rigonda, who is the second Lithuanian teacher to succeed in the TIWI competition in 2020, decided to teach "uniformly accelerated motion" employing a non-traditional approach i.e. a self-designed Inquiry-based learning scenario which includes computer programming activities to be carried out with Scratch.

Due to the outbreak of the Covid-19 pandemic Rigonda's class – i.e. a total of 15 students of 17 years of age – conducted all activities online, through a distance learning session which took place on the 28th of April 2020 and lasted 2 hours. All teaching material was gathered and shared through the social learning platform Graasp, which was also employed to set-up the Inquiry-based learning scenario and carry out all the activities. The Inquiry-based learning scenario was also made available via the Go-lab eco-system for online STEM teaching.

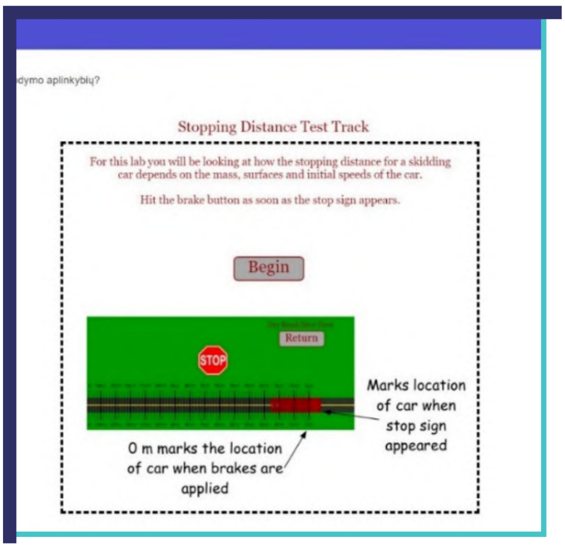


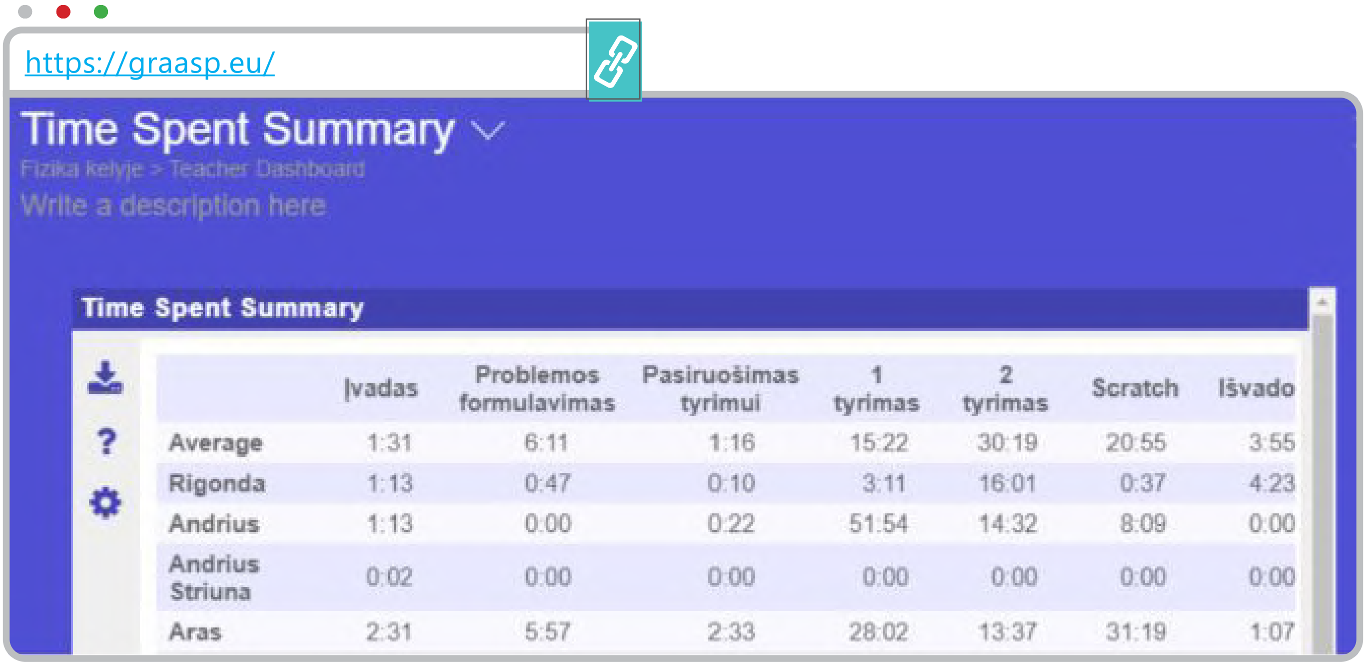
Figure 5. Evidence of remote IBLS implementation in Lithuania – Uniformly Accelerated Motion

Rigonda did not find any difficulties in implementing the Inquiry-based learning scenario and confirms that using virtual experiments and coding increases students' attention and motivation in learning physics.

Nevertheless, she admitted that some students experienced difficulties in filling in tables, drawing graphs or conducting self-assessments, possibly due to the heavy traffic in the server at the time of implementation, or due to students' inadequate computer settings.

In Rigonda's experience, the Inquiry-based approach allowed students to work more independently, kept them focused on the topic under analysis and produced better results than a classical approach based on direct instructions. In addition, by presenting "uniformly accelerated motion" through real life experiments students could easily understand the usefulness of the knowledge built for some professions e.g. test driver, professional driver, etc.

Based on her experience, Rigonda would advise other teachers to adopt different technologies in their lessons. She recommends to use Graasp's different applications as they provide teachers with useful tools to monitor students' activities e.g. the analyse of student's time management during the implementation of learning scenarios.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Time Spent Summary

Fizika kelyje > Teacher Dashboard

Write a description here

Time Spent Summary

	Įvadas	Problemos formulavimas	Pasiruošimas tyrimui	1 tyrimas	2 tyrimas	Scratch	Išvado
Average	1:31	6:11	1:16	15:22	30:19	20:55	3:55
Rigonda	1:13	0:47	0:10	3:11	16:01	0:37	4:23
Andrius	1:13	0:00	0:22	51:54	14:32	8:09	0:00
Andrius Striuna	0:02	0:00	0:00	0:00	0:00	0:00	0:00
Aras	2:31	5:57	2:33	28:02	13:37	31:19	1:07

Figure 6. Evidence of remote IBLS implementation in Lithuania – Uniformly Accelerated Motion

PROGRAMMING AN AUTOMATIC BRIDGE

Stefania Matzari – Olohmero Dhmotiko Scholio To Kryfo Scholio, Limassol, Cyprus – invited students to convert a bridge, already designed during a previous classroom assignment, into an automatic bridge.

The lesson, which was designed to associate learning activities and civil engineering practice, was conducted over 90 minutes between the 20th and the 27th of February 2020. A total of 50 students of 11 years of age successfully participated to the self-designed Learning scenario, which was carried out and shared via Graasp and Go-Lab.

https://graasp.eu/

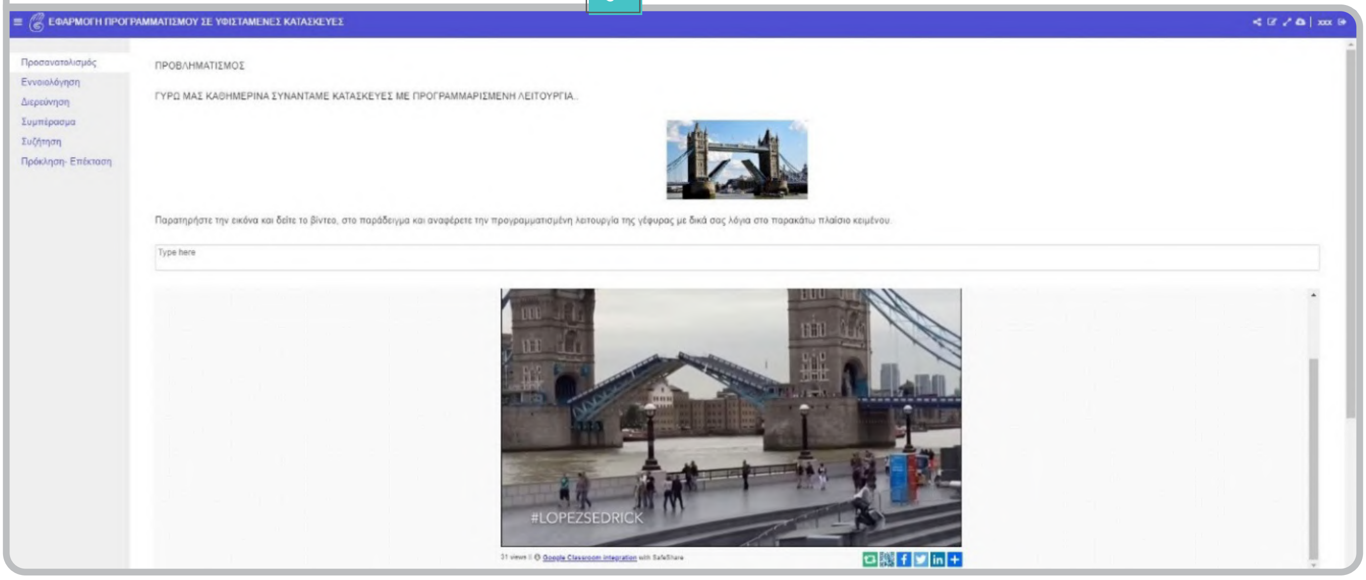

Figure 7. Evidence of IBLS implementation in Cyprus – Programming an automatic bridge

Although no major problems were faced during the implementation of the Inquiry-based learning scenario, Stefania admitted that some students found it hard to work with the applications integrated in the self-designed Learning scenario – i.e. Scratch and Engine Pro – perhaps because of their young age.

https://graasp.eu/

Figure 8. Evidence of IBLS implementation in Cyprus – Programming an automatic bridge

Nonetheless, students' attention was highly captured by all the investigation activity required by the Learning scenario, which resulted in students' great engagement during the entire experience.

For this reason, in Stefania's experience the use of Inquiry-based learning is very beneficial for classes on Robotics and Computer Programming: such an approach fosters the development of critical as well as computational thinking while promoting collaborative learning.

Findings

The survey conducted in four countries – i.e. Cyprus, France, Lithuania, and Spain – on both teachers and students, confirmed the validity of the instruments employed as well as the relevance of the methodological framework used for the study.

With reference to students, results show that conducting an ICT Inquiry-based learning experience increases programming self-efficacy (Table 4). However, this effect needs to be discussed in accordance with the programming component in the design of the Inquiry Learning Spaces which were developed and implemented in the frame of the TIWI project.

According to the data analysis, the student sample after the implementations of the Inquiry Learning Spaces can be distinguished into two different clusters based on student responses in the scales of the instrument (Table 5).

Student Cluster 1 (50.16%) presents increased average responses across all scales, as compared to the responses of Student Cluster 2 (49.84%), which proved highly significant in the statistical test which was conducted.

This finding implies that the student sample is evenly split in a student cluster of consistently higher ability and attitudes (Student Cluster 1), and another cluster of consistently lower ability and attitudes.

Interestingly, further analysis showed that students in Cluster 1, as compared to students in Cluster 2, had more prior learning experience with Inquiry-based learning (Likelihood ratio Chi-Square = 13.86, $p < 0.001$), and programming (Likelihood ratio Chi-Square = 7.08, $p < 0.01$) in school; they had worked more with computers in STEM-related classes in their classrooms (Likelihood ratio Chi-Square = 38.75, $p < 0.001$) and outside their schools (Likelihood ratio Chi-Square = 15.23, $p < 0.001$); and they had used more the Go-Lab ecosystem in the past (Likelihood ratio Chi-Square = 12.97, $p < 0.001$).

As it concerns teachers (see Table 6), although an improvement for all scales is recorded in the post experience survey responses, this improvement is statistically significant in the case of computational thinking only ($Z = -2.35$, $p < 0.05$). Nonetheless, the correlational analysis showed that improvement in one scale is accompanied by improvement in the rest of the scales (Table 7).

The outcomes of the survey are complemented and, in some cases, corroborated by the observations gathered via the case-study analysis. Indeed, the analysis of case studies provides evidence on student's curiosity and positive attitude towards coding when this activity is included in a well-designed Inquiry-based learning scenario. Indeed, the stories of implementation analysed show that students are positively surprised and eager to carry out coding activities if they can clearly associate their practical experience to a concrete outcome e.g. a video representing the water life cycle, future possible career paths, etc.

In addition, students' curiosity towards coding might facilitate teacher's presentation of the importance of coding in different jobs nowadays. Based on the implementation stories collected, after experiencing an Inquiry-based learning scenario including coding activities students seem to listen with more attention to teachers' discussions on the possibilities offered by coding in many fields of work.

Teachers who are used to employ Inquiry-based learning scenarios with coding activities tend to consider teenage students as native digital citizens. Hence, they are more likely to plan and use coding activities in the future and consider new technologies very useful for teaching STEM subjects.

Although enthusiastic about the use of Inquiry-based learning scenarios, some of the teachers whose stories were collected admitted that they had difficulties in creating and/or implementing Inquiry-based learning scenarios in the past. To gain the required knowledge and confidence in using such instruments, they participated to dedicated training sessions, workshops and summer schools and would strongly suggest doing so to colleagues who do not feel at ease with IBLSs.

Although teachers seem to be very open to the use of ICT in the classroom, often they have very limited time to use online applications and platforms due to curriculum overload. In addition, they admit that the use of ICT might require personal assistance to some students who are not independent ICT users and recognise that students' degree of independence in coding is closely related to their age.

Recommendations

Based on the outcomes of the surveys conducted as well as the case-studies analysed, the following recommendations are formulated with special reference to teachers, headmasters and policy makers.

FOR TEACHERS:

- To maximise the impact of an ICT Inquiry-based learning activity, make sure that students get good introductions to the Inquiry approach and the process to be used prior to starting the experience.
- Use real life examples – see section on case-studies for inspiration – to ignite students' interest and involve them as much as possible in all steps of the Inquiry process.
- Associate ICT Inquiry-based activities to information on jobs and possible careers to enhance students interests and engagement to the activity – see section on case-studies for inspiration.
- The afore mentioned questionnaires can be administered either on paper or via a free online tool like Microsoft Forms, Google Forms, or SurveyMonkey. In the case of online tools, the provided data analysis and visualisations based on the collected data will strengthen teachers' understanding of their students' status and needs and will also promote exchanges with other actors i.e. fellow teachers, headmasters. Questionnaires can also be used in a modular form and compile a shorter, personalised version of the instrument, based on students' individual needs.
- Depending on students' age, use the self-assessment questionnaires available on the TIWI website or the ones in appendix 1 and 2 of this document, as part of the introduction to the Inquiry approach.
- Allow enough time for the students to comprehend the questions and discuss their results in small groups or with the entire classroom.
- For younger students, the questionnaires can be used as a basis for guided group discussion with the support of the teacher.
- Depending on students' age and their experience on coding and Inquiry-based learning, guidance might be needed throughout the intervention. The promotion of collaboration and group work, the provision of supportive material and guidelines are some examples of approaches that can be adopted.

HEADMASTERS/POLICY MAKERS:

- As the study shows the validity of the Inquiry-based approach to learn ICT, it needs to be emphasized at all levels of education that Inquiry-based learning connects to ICT and enhances its teaching i.e. real-world problem solving, communication, exploration, development of critical thinking at different ages and development stages, etc. This can be done via the organisation of targeted trainings, the promotion of good practices and learning activities developed by teachers for teachers and the inclusion of clarifications and suggestions on how to use the Inquiry-based approach to learn ICT to curricula implementation instructions.
- Certain adaptations to the Teacher Training Institutions' programmes can facilitate and foster the teaching and learning of ICT through the Inquiry-based approach. The use of Graasp and the presentation of the learning activities that have been produced and tested by the TIWI project, can be incorporated to the TTIs programme and form the stepstone to the development of novice teachers' Inquiry-based skills.
- The induction of new teachers can be adapted and designed in a way to familiarize novice teachers with Inquiry-based learning and its applications to teaching various subjects including ICT. Novice teachers' mentors providing both pedagogical and administrative support, have a significant role to play in this.

Finally, Ministers of Education can foster Inquiry-based learning by encouraging and facilitating the use of the self-assessment questionnaires designed within the context of TIWI.

Available on TIWI website in English, Lithuanian, French and Spanish, the self-assessment questionnaires are an easy to use tool that teachers can employ prior to and after their involvement in Inquiry-based learning activities to assess their ease and familiarity in employing such a pedagogical approach to teach ICT.

By providing a targeted and immediate feedback on the ICT knowledge owned before being involved in Inquiry-based activities and the one gathered as a result of this practice, the tool is also a valid instrument for students to self-assess their ICT knowledge and to engage them in ICT Inquiry-based learning.

Indeed, two types of self-assessment questionnaires have been designed and are currently available, i.e. one for teachers and another one for students. Both types of questionnaires should be filled in before and after involvement in one or more ICT Inquiry-based learning activity. By comparing the results obtained before and after the ICT Inquiry-based experience, teachers and students can easily measure the impact of ICT Inquiry-based activities on their teaching or learning experience.

http://tiwi.eun.org/self-assessment-tool/

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Appendix 1: Teachers' questionnaire

Socio-demographic characteristics

What is your gender? (Female/Male/Prefer not to say)
What is your age (in years)?

Prior experience

How many years have you been in service in education? (Years)
Have you studied STEM-related postgraduate studies? (Yes/No)
Have you followed STEM-related professional development? (Yes/No)
Do you have STEM-related experience with computer-supported learning environments? (Yes/No)
Have you ever used the Go-Lab ecosystem in the past? (Yes/No)

Work environment (How well does your work environment meet the following criteria? 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Interactive Whiteboards are available in the classroom	○	○	○	○	○
Students have access to digital devices (laptops, tablets, smartphones) in the classroom	○	○	○	○	○
The school's internet connection is reliable and fast	○	○	○	○	○
Students have access to digital devices connected to the Internet at home	○	○	○	○	○
The school administration supports the integration of digital technologies in the classroom	○	○	○	○	○
The curriculum facilitates and supports the use of digital technologies in the classroom	○	○	○	○	○
My colleagues use digital technologies in the classroom	○	○	○	○	○

Instructional design (Developed by UCY; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
It is easy for me to start designing lesson plans for computer-supported learning environments	○	○	○	○	○
It is easy for me to change a lesson plan in a computer-supported learning environment to adapt it to the needs of my students	○	○	○	○	○

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I feel competent in using virtual laboratories for lesson plans in computer-supported learning environments	○	○	○	○	○
When I find a virtual laboratory, it is easy for me to integrate it in my lesson plans for computer-supported learning environments	○	○	○	○	○
It is easy for me to design a virtual experimentation for computer-supported learning environments	○	○	○	○	○
I know how to configure software scaffolds to adapt them to the needs of my students	○	○	○	○	○
I feel competent to include instructions to support student work in lesson plans for computer-supported learning environments	○	○	○	○	○
It is easy for me to integrate programming in lesson plans for computer-supported learning environments	○	○	○	○	○

Responsive instruction (Developed by UCY; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
It is easy for me to respond to unexpected questions of students while they are working in computer-supported learning environments	○	○	○	○	○
I know what to do when my students face difficulties in executing a learning task in a computer-supported learning environment	○	○	○	○	○
I know what to do when my students arrive at an unexpected experimental finding in a computer-supported learning environment	○	○	○	○	○
I know what to do when my lesson plan in a computer-supported learning environment has not worked well	○	○	○	○	○
It is easy for me to switch between student individual work and student group work in computer-supported learning environments	○	○	○	○	○
After I have implemented a lesson plan in a computer-supported learning environment, I know which aspects to change to improve my instruction	○	○	○	○	○
I would prefer to use my own lesson plan in a computer-supported learning environment than to use the lesson plan of an experienced colleague	○	○	○	○	○
I know which questions to ask to colleagues to discuss their experience with a lesson plan in a computer-supported learning environment	○	○	○	○	○

Formative assessment in computer-supported learning environments (Developed by UCY; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I know which aspects of student work to focus on to assess their performance in computer-supported learning environments	○	○	○	○	○
I feel competent to diagnose student performance in computer-supported learning environments	○	○	○	○	○
I know when to intervene to track student performance in computer-supported learning environments	○	○	○	○	○
I feel competent to provide timely feedback to students while they are working in computer-supported learning environments	○	○	○	○	○
I feel competent to track student performance in computer-supported learning environments after I give them my feedback	○	○	○	○	○
I know how to evaluate student learning products for formative assessment purposes in computer-supported learning environments	○	○	○	○	○
I know how to evaluate student portfolios for formative assessment purposes in computer-supported learning environments	○	○	○	○	○
Student performance in computer-supported learning environments is always improved after I give them my feedback	○	○	○	○	○

Computational thinking (Source: Bean et al. 2015; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I feel confident writing simple programs for the computer	○	○	○	○	○
I know how to teach programming concepts effectively	○	○	○	○	○
I can promote a positive attitude towards programming in my students	○	○	○	○	○
I can guide students in using programming as a tool while we explore other topics	○	○	○	○	○
I feel confident using programming as an instructional tool within my classroom	○	○	○	○	○
I can adapt lesson plans incorporating programming as an instructional tool	○	○	○	○	○
I can create original lesson plans incorporating programming as an instructional tool	○	○	○	○	○
I can identify how programming concepts relate to curriculum standards	○	○	○	○	○

Technology knowledge (TPACK scale, Source: Schmidt et al. 2009; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I know how to solve my own technical problems	○	○	○	○	○
I can learn technology easily	○	○	○	○	○
I keep up with important new technologies	○	○	○	○	○
I frequently play around the technology	○	○	○	○	○
I know about a lot of different technologies	○	○	○	○	○
I have the technical skills I need to use technology	○	○	○	○	○

Science content knowledge (TPACK scale, Source: Schmidt et al. 2009; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I have sufficient knowledge about STEM	○	○	○	○	○
I have the knowledge required to teach STEM	○	○	○	○	○
I have a very good understanding of STEM	○	○	○	○	○
I have mastered STEM content	○	○	○	○	○

Pedagogical knowledge (TPACK scale, Source: Schmidt et al. 2009; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I know how to assess student performance in a classroom	○	○	○	○	○
I can adapt my teaching based-upon what students currently understand or do not understand	○	○	○	○	○
I can adapt my teaching style to different students	○	○	○	○	○
I can assess student learning in multiple ways	○	○	○	○	○
I can use a wide range of teaching approaches in a classroom setting	○	○	○	○	○
I am familiar with common student understandings and misconceptions	○	○	○	○	○
I know how to organize and maintain classroom management	○	○	○	○	○

Pedagogical content knowledge (TPACK scale, Source: Schmidt et al. 2009; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I can select effective teaching approaches to guide students thinking and learning in STEM	O	O	O	O	O
I am aware of the different approaches for teaching STEM	O	O	O	O	O
I know pedagogical theories/models that apply to teaching STEM	O	O	O	O	O
I know teaching strategies that could be used for improving teaching STEM	O	O	O	O	O

Technological content knowledge (TPACK scale, Source: Schmidt et al. 2009; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I can select effective technologies for understanding and doing STEM	O	O	O	O	O
I am aware of the different technologies that can be used for understanding and doing STEM	O	O	O	O	O
I have been trained to use different technologies that can be used for learning STEM	O	O	O	O	O
Several technologies exist for understanding and doing STEM	O	O	O	O	O

Technological pedagogical knowledge (TPACK scale, Source: Schmidt et al. 2009; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I can choose technologies that enhance the teaching approaches for a lesson	O	O	O	O	O
I can choose technologies that enhance students' learning for a lesson	O	O	O	O	O
My teacher education program has caused me to think more deeply about how technology could influence the teaching approaches I use in my classroom	O	O	O	O	O
I am thinking critically about how to use technology in my classroom	O	O	O	O	O
I can adapt the use of the technologies that I am learning about to different teaching activities	O	O	O	O	O
I can select technologies to use in my classroom that enhance what I teach, how I teach and what students learn	O	O	O	O	O

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I can use strategies that combine content, technologies and teaching approaches that I learned about in my coursework in my classroom	○	○	○	○	○
I can choose technologies that enhance the content for a lesson	○	○	○	○	○

Technological pedagogy and content knowledge (TPACK scale, Source: Schmidt et al. 2009; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I can design lessons that appropriate combine science, technologies and teaching approaches	○	○	○	○	○
I can teach lessons that appropriate combine science, technologies and teaching approaches	○	○	○	○	○
I know how to blend science, technologies and teaching approaches for teaching purposes	○	○	○	○	○
I use science, technologies and teaching (all together) in my teaching	○	○	○	○	○

Efficacy in teaching Inquiry-based STEM (Source: Enochs & Riggs 1990; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I will continually find better ways to teach Inquiry-based STEM	○	○	○	○	○
Even if I try very hard, I will not teach Inquiry-based STEM as well as I will through other approaches	○	○	○	○	○
I know the steps necessary to teach STEM concepts through Inquiry effectively	○	○	○	○	○
I will not be very effective in monitoring Inquiry-based STEM experiments	○	○	○	○	○
When a student has difficulty understanding an Inquiry process, I know how to help the student to understand it better	○	○	○	○	○
I understand Inquiry well enough to be effective in teaching STEM through Inquiry	○	○	○	○	○
I know how to explain to my students to conduct Inquiry-based STEM	○	○	○	○	○
I will typically be able to answer students' questions about Inquiry	○	○	○	○	○

Appendix 2. Students' questionnaire

Socio-demographic characteristics

What is your gender? (Girl/Boy/Prefer not to say)
What is your age (in years)?
What grade are you in? (3rd to 12th)

Prior experience

Have you ever had any prior learning experience with Inquiry-based learning in school? (Yes/No)
Have you ever had any prior experience with programming in school? (Yes/No)
Have you ever worked with computers in your STEM-related classes in school? (Yes/No)
Have you ever worked with computers in your STEM-related classes outside school? (Yes/No)
Have you ever used the Go-Lab ecosystem in the past? (Yes/No)

Identifying variables (TIPSII, Source: Burns et al., 1985)
A football coach thinks his team loses because his players lack strength. He decides to study factors that influence strength. Which of the following variables might the coach study to see if it affects the strength of the players?

A. Amount of vitamins taken each day.
B. Amount of lifting exercises done each day.
C. Amount of time spent doing exercises.
D. All of the above. [Correct response]

An auto manufacturer wants to make cars cheaper to operate. They are studying variables that may affect the number of miles per gallon that autos get. Which variable is likely to affect the number of miles per gallon?

A. Weight of. the car.
B. Size of the motor.
C. Color of the car.
D. Both A and B. [Correct response]

Marie wondered if the earth and oceans are heated equally by sunlight. She decided to conduct an investigation. She filled a bucket with dirt and another bucket of the same size with water. She placed them so each bucket received the same amount of sunlight. The temperature in each was measured every hour from 8:00 a.m. to 6:00 p.m.
Which of these variables is controlled in the study?

A. Kind of water placed in the bucket.
B. Temperature of the water and soil.
C. Type of material placed in the buckets.
D. Amount of time each bucket is in the sun. [Correct response]

What was the dependent or responding variable?

A. Kind of water placed in the bucket.
B. Temperature of the water and soil. [Correct response]
C. Type of material placed in the buckets.
D. Amount of time each bucket is in the sun.

What was the independent or manipulated variable?

A. Kind of water placed in the bucket.
B. Temperature of the water and soil.
C. Type of material placed in the buckets. [Correct response]
D. Amount of time each bucket is in the sun.

Joe wanted to find out if the temperature of water affected the amount of sugar that would dissolve in it. He put 50 ml. of water into each of four identical jars. He changed the temperatures of the jars of water until he had one at 0oC, one at 50oC, one at 75oC, and one at 95oC. He then dissolved as much sugar as he could in each jar by stirring.

What is a controlled variable in this study?

A. Amount of sugar dissolved in each jar.
B. Amount of water placed in each jar. [Correct response]
C. Number of jars used to hold water.
D. The temperature of the water.

What is the dependent or responding variable?

A. Amount of sugar dissolved in each jar. [Correct response]
B. Amount of water placed in each jar.
C. Number of jars used to hold water.
D. The temperature of the water.

What is the independent or manipulated variable?

A. Amount of sugar dissolved in each jar.
B. Amount of water placed in each jar.
C. Number of jars used to hold water.
D. The temperature of the water. [Correct response]

A study was done to see if leaves added to soil had an effect on tomato production. Tomato plants were grown in four large tubs. Each tub had the same kind and amount of soil. One tub had 15 kg of rotted leaves mixed in the soil and a second had 10 kg. A third tub had 5 kg and the fourth had no leaves added. Each tub was kept in the sun and watered the same amount. The number of kilograms of tomatoes produced in each tub was recorded.

What is a controlled variable in this study?

A. Amount of tomatoes produced in each tub.
B. Amount of leaves added to the tubs.
C. Amount of soil in each tub. [Correct response]
D. Number of tubs receiving rotted leaves.

What is the dependent or responding variable?

A. Amount of tomatoes produced in each tub. [Correct response]
B. Amount of leaves added to the tubs.
C. Amount of soil in each tub.
D. Number of tubs receiving rotted leaves.

What is the independent or manipulated variable?

A. Amount of tomatoes produced in each tub.
B. Amount of leaves added to the tubs. [Correct response]
C. Amount of soil in each tub.
D. Number of tubs receiving rotted leaves.

Mr. Bixby has an all-electric house and is concerned about his electric bill. He decides to study factors that affect how much electrical energy he uses. Which variable might influence the amount of electrical energy used?

A. The amount of television the family watches.
B. The location of the electric meter.
C. The number of baths taken by family members.
D. A and C. [Correct response]

Identifying and Stating Hypotheses (TIPSII, Source: Burns et al., 1985)

A class is studying the speed of objects as they fall to the earth. They design an investigation where bags of gravel weighing different amounts will be dropped from the same height. In their investigation, which of the following is the hypothesis they would test about the speed of objects falling to earth?

A. An object will fall faster when it is dropped further.
B. The higher an object is in the air the faster it will fall.
C. The larger the pieces of gravel in a bag the faster it will fall.
D. The heavier an object the faster it will fall to the ground. [Correct response]

A police chief is concerned about reducing the speed of autos. He thinks several factors may affect automobile speed. Which of the following is a hypothesis he could test about how fast people drive?

A. The younger the drivers, the faster they are likely to drive. [Correct response]
B. The larger the autos involved in an accident, the less likely people are to get hurt.
C. The more policemen on patrol, the fewer the number of auto accidents.
D. The older the autos, the more accidents they are likely to be in.

A farmer wonders how he can increase the amount of corn he grows. He plans to study factors that affect the amount of corn produced. Which of these hypotheses could he test?

A. The greater the amount of fertilizer the larger the amount of corn produced. [Correct response]
B. The greater the amount of corn, the larger the profits for the year.
C. As the amount of rainfall increases, the more effective the fertilizer.
D. As the amount of corn produced increases, the cost of production increases.

Marie wondered if the earth and oceans are heated equally by sunlight. She decided to conduct an investigation. She filled a bucket with dirt and another bucket of the same size with water. She placed them so each bucket received the same amount of sunlight. The temperature in each was measured every hour from 8:00 a.m. to 6:00 p.m. Which hypothesis was being tested?

A. The greater the amount of sunlight, the warmer the soil and water become.
B. The longer the soil and water are in the sun, the warmer they become.
C. Different types of material are warmed differently by the sun. [Correct response]
D. Different amounts of sunlight are received at different times of the day.

Susan is studying food production in bean plants. She measures food production by the amount of starch produced. She notes that she can change the amount of light, the amount of carbon dioxide, and the amount of water that plants receive. What is a testable hypothesis that Susan could study in this investigation?

A. The more carbon dioxide a bean plant gets the more starch it produces. [Correct response]
B. The more starch a bean plant produces the more light it needs.
C. The more water a bean plant gets the more carbon dioxide it needs.
D. The more light a bean plant receives the more carbon dioxide it will produce.

Joe wanted to find out if the temperature of water affected the amount of sugar that would dissolve in it. He put 50 ml of water into each of four identical jars. He changed the temperatures of the jars of water until he had one at 0°C, one at 50°C, one at 75°C, and one at 95°C. He then dissolved as much sugar as he could in each jar by stirring. What is the hypothesis being tested?

A. The greater the amount of stirring, the greater the amount of sugar dissolved.
B. The greater the amount of sugar dissolved, the sweeter the liquid.
C. The higher the temperature, the greater the amount of sugar dissolved. [Correct response]
D. The greater the amount of water used, the higher the temperature.

Some students are considering variables that might affect the time it takes for sugar to dissolve in water. They identify the temperature of the water, the amount of sugar and the amount of water as variables to consider. What is a hypothesis the students could test about the time it takes for sugar to dissolve in water?

A. The larger the amount of sugar the more water required to dissolve it.
B. The colder the water the faster it has to be stirred to dissolve.
C. The warmer the water the more sugar -that will dissolve.
D. The warmer the water the more time it takes the sugar to dissolve. [Correct response]

A study was done to see if leaves added to soil had an effect on tomato production. Tomato plants were grown in four large tubs. Each tub had the same kind and amount of soil. One tub had 15 kg of rotten leaves mixed in the soil and a second had 10 kg. A third tub had 5 kg and the fourth had no leaves added. Each tub was kept in the sun and watered the same amount. The number of kilograms of tomatoes produced in each tub was recorded. What is the hypothesis being tested?

A. The greater the amount of sunshine the greater the amount of tomatoes produced.
B. The larger the tub, the greater the amount of leaves added.
C. The greater the amount of water added, the faster the leaves rotted in the tubs.
D. The greater the amount of leaves added, the greater the amount of tomatoes produced. [Correct response]

Ann has an aquarium in which she keeps goldfish. She notices that the fish are very active sometimes but not at others. She wonders what affects the activity of the fish. What is a hypothesis she could test about factors that affect the activity of the fish?

A. The more you feed fish, the larger the fish become.
B. The more active the fish, the more food they need.
C. The more oxygen in the water, the larger the fish become.
D. The more light on the aquarium, the more active the fish. [Correct response]

Operationally Defining (TIPSII, Source: Burns et al., 1985)
A study of auto efficiency is done. The hypothesis tested is that a gasoline additive will increase auto efficiency. Five identical cars each receive the same amount of gasoline but with different amounts of Additive A. They travel the same track until they run out of gasoline.

The research team records the number of miles each car travels. How is auto efficiency measured in this study?

A. The time each car runs out of gasoline.
B. The distance each car travels. [Correct response]
C. The amount of gasoline used.
D. The amount of Additive A used.

The effect of wheel width on ease of rolling is being studied by a science class. The class puts wide wheels onto a small cart and lets it roll down an inclined ramp and then across the floor. The investigation is repeated using the same cart but this time fitted with narrow wheels. How could the class measure ease of rolling?

A. Measure the total distance the cart travels. [Correct response]
B. Measure the angle of the inclined ramp.
C. Measure the width of each of the two sets of wheels.
D. Measure the weight of each of the carts.

A gardener notices that his squash plants are being attacked by aphids. He needs to get rid of the aphids. His brother tells him that "Aphid-Away" powder is the best insecticide to use. The county agent says "Squash-Saver" spray works best. The gardener selects six squash plants and applies the powder to three and the spray to three. A week later he counts the number of live aphids on each of the plants. How is the effectiveness of the insecticides measured in this study?

A. Measuring the amount of spray or powder used.
B. Determining the condition of the plants after spraying or dusting.
C. Weighing the squash each plant produces.
D. Counting the number of aphids remaining on the plants. [Correct response]

Lisa wants to measure the amount of heat energy a flame will produce in a certain amount of time. A burner will be used to heat a beaker containing a 1iter of cold water for ten minutes. How will Lisa measure the amount of heat energy produced by the flame?

A. Note the change in water temperature after ten minutes. [Correct response]
B. Measure the volume of water after ten minutes.
C. Measure the temperature of the flame after ten minutes.
D. Calculate the time it takes for the litre of water to boil.

A biologist tests this hypothesis: the greater the amount of vitamins given to rats the faster they will grow. How can the biologist measure how fast rats will grow?

A. Measure the speed of the rats.
B. Measure the amount of exercise the rats receive.
C. Weigh the rats every day. [Correct response]
D. Weigh the amount of vitamins the rats will eat.

A student is investigating the lifting ability of magnets. He has several magnets of different sizes and shapes. For each magnet, the student weighs the amount of iron filings it picks up. How is the lifting ability of a magnet defined in the experiment?

A. The size of the magnet in use.
B. The weight of the magnet picking up things.
C. The shape of the magnet in use.
D. The weight of the iron filings picked up. [Correct response]

Designing Investigations (TIPSII, Source: Burns et al., 1985)

Jim thinks that the more air pressure in a basketball, the higher it will bounce. To investigate this hypothesis he collects several basketballs and an air pump with a pressure gauge. How should Jim test his hypothesis?

A. Bounce basketballs with different amounts of force from the same height.
B. Bounce basketballs having different air pressures from the same height. [Correct response]
C. Bounce basketballs having the same air pressure at different angles from the floor.
D. Bounce basketballs having the same amount of air pressure from different heights.

A greenhouse manager wants to speed up the production of tomato plants to meet the demands of anxious gardeners. She plants tomato seeds in several trays. Her hypothesis is that the more moisture seeds receive the faster they sprout. How can she test this hypothesis?

A. Count the number of days it takes seeds receiving different amounts of water to sprout. [Correct response]
B. Measure the height of the tomato plants a day after each watering.
C. Measure the amount of water used by plants in different trays.
D. Count the number of tomato seeds placed in each of the trays.

Mark is studying the effect of temperature on the rate that oil flows. His hypothesis is that as the temperature of the oil increases it flows faster. How could he test this hypothesis?

A. Heat oil to different temperatures and weigh it after it flows out of the can.
B. Observe the speed at which oil at different temperatures flows down a smooth surface. [Correct response]
C. Let oil flow down smooth surfaces at different angles and observe its speed.
D. Measure the time it takes for oil of different thicknesses to pour out of the can.

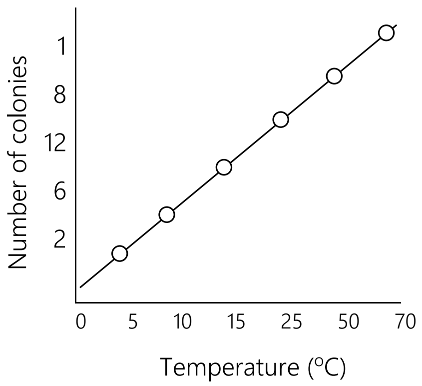
Graphing and Interpreting (TIPSII, Source: Burns et al., 1985)

A student in a science class studied the effect of temperature on the growth of bacteria. The student obtained the following data:

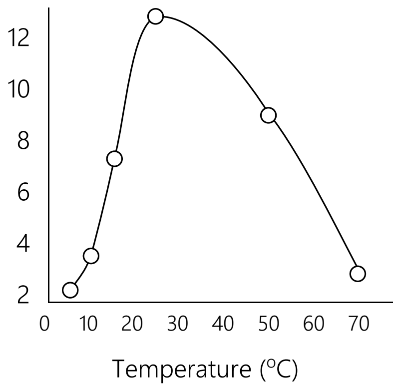
Temperature of growth chamber (°C)	Number of bacterial colonies
5	0
10	2
15	6
25	12
50	8
70	1

Which graph correctl y represents the data from the experiment? [Correct response: B]

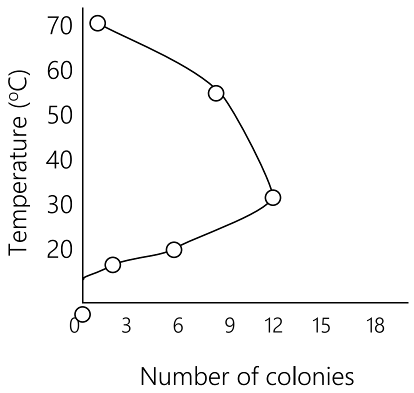
A.



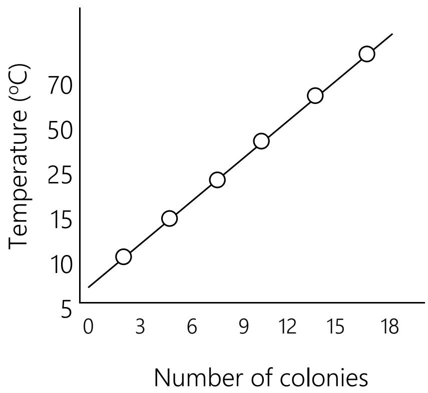
B.



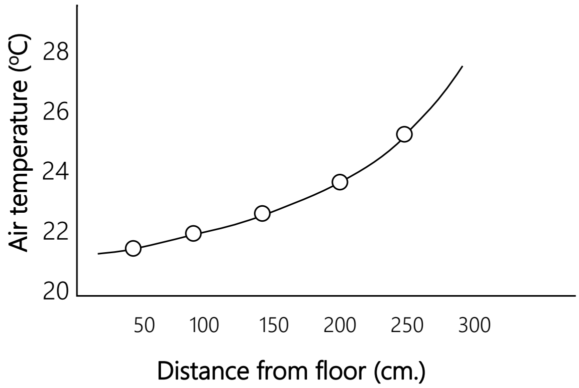
C



D



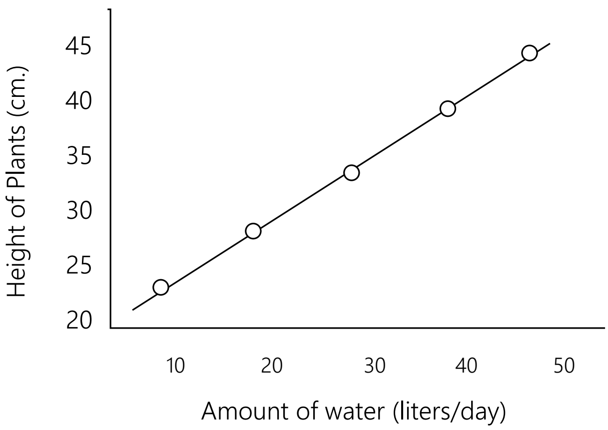
A study is done of the temperature in a room at different distances above the floor. The graph of the data is shown below. How are the variables related?



A. As distance from the floor increases, air temperature decreases.
B. As distance from the floor increases, air temperature increases. [Correct response]
c. An increase in air temperature means floor means a decrease in distance from the floor.
D. The distance from the floor is not related to air temperature increases.

A study is being done on the amount of water needed to grow plants. Five small plots are given different amounts of water. After two months the height of the plants is measured. The data are shown in the graph. What is the relationship between the variables?

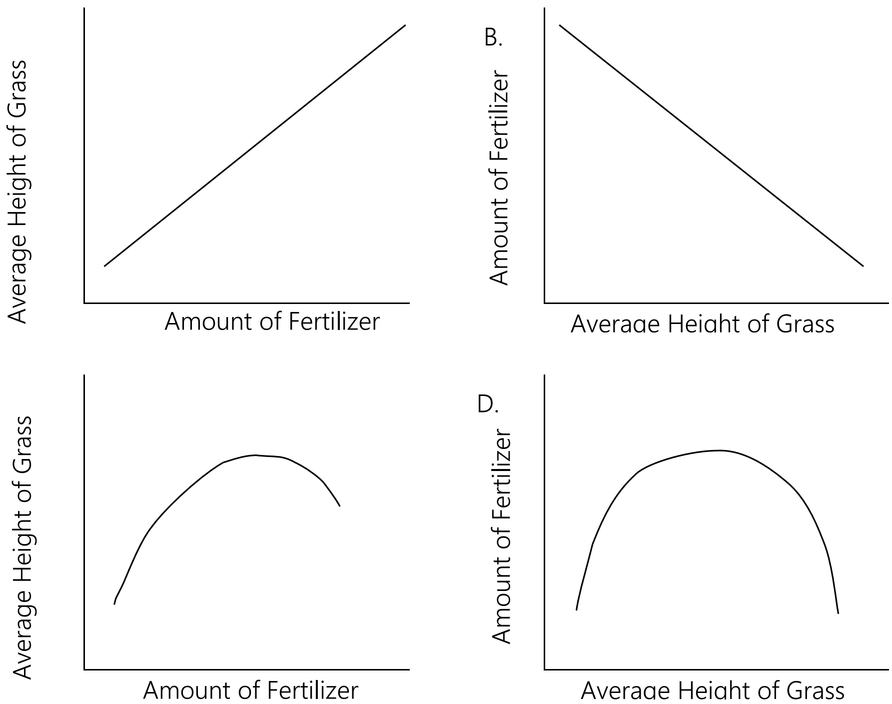
A. Increasing the amount of water increases the height of the plants. [Correct response]
B. Increasing the height of the plants increases the amount of water.
C. Decreasing the amount of water increases the height of the plants.
D. Decreasing the height of the plants decreases the amount of water.



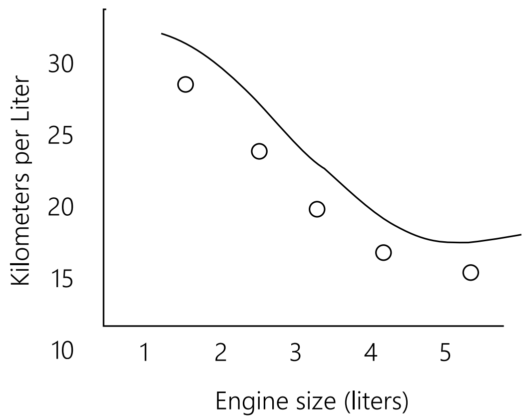
A researcher is testing a new fertilizer. Five small fields of the same size are used. Each field receives a different amount of fertilizer. One month later the average height of the grass in each plot is measured. The measurements are shown in the table below.

Amount of Fertilizer (kg)	**Average Height of Grass (cm.)**
10	7
30	10
50	12
80	14
100	12

Which graph represents the data in the table? [Correct response: C]



A consumer group measures the miles per gallon cars get with different size engines. The results are as follows:



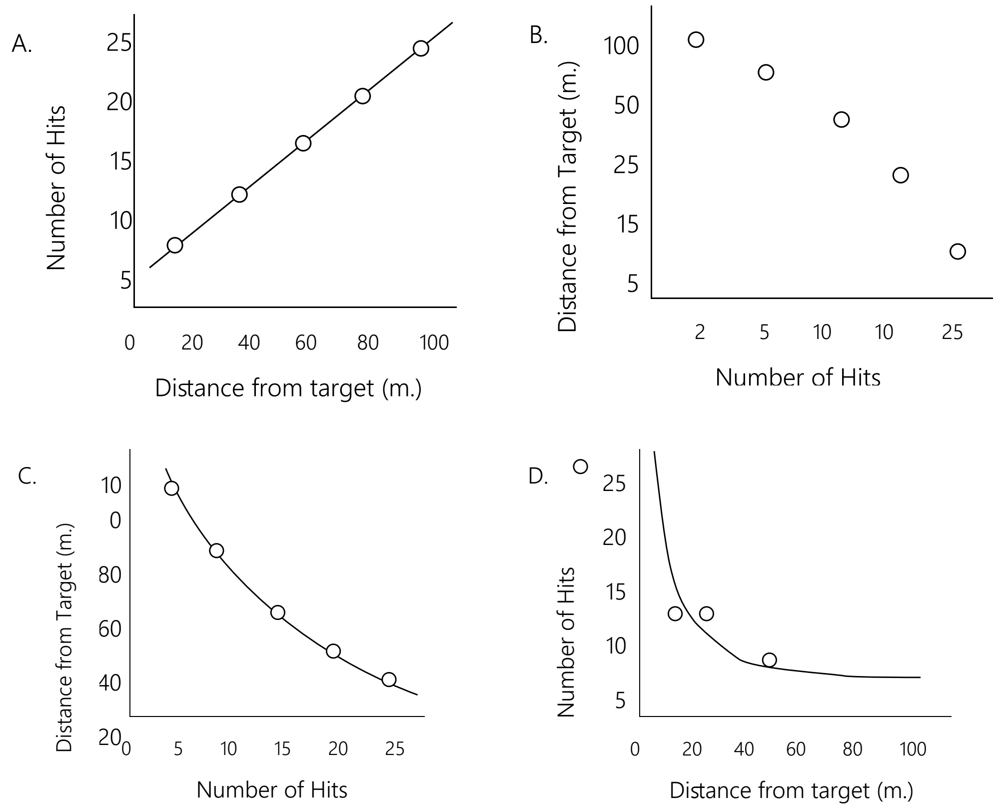
Which of the following describes the relationship between the variables?

A. The larger the engine the more miles per gallon the car gets.
B. The fewer miles per gallon the car gets the smaller the engine.
C. The smaller the engine the more miles per gallon a car gets. [Correct response]
D. The more miles per gallon for a car the larger the engine.

Twenty-five shots are fired at a target from several distances. The table below shows the number of “hits” in 25 shots at each distance.

Distance from Target (m.)	Number of Hits
5	25
15	10
25	10
50	5
100	2

Which graph best represents the data? [Correct response: D]



Learning science in school (Student attitudes; Source: Kind et al., 2007; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
We learn interesting things in science lessons	○	○	○	○	○
I look forward to my science lessons	○	○	○	○	○
Science lessons are exciting	○	○	○	○	○
I would like to do more science at school	○	○	○	○	○
I like Science better than most other subjects at school	○	○	○	○	○
Science is boring	○	○	○	○	○

Science outside of school (Student attitudes; Source: Kind et al., 2007; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I would like to join a science club (if there would be available such clubs)	○	○	○	○	○
I like watching science programmes on TV	○	○	○	○	○
I like to visit science museums	○	○	○	○	○
I would like to do more science activities outside school	○	○	○	○	○
I like reading science magazines and books	○	○	○	○	○
It is exciting to learn about new things happening in science	○	○	○	○	○

Future participation in science (Student attitudes; Source: Kind et al., 2007; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I would like to study more science in the future	○	○	○	○	○
I would like to study science at university	○	○	○	○	○
I would like to have a job working with science	○	○	○	○	○
I would like to become a scientist	○	○	○	○	○

Importance of science (Student attitudes; Source: Kind et al., 2007; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Science and technology is important for society	O	O	O	O	O
Science and technology makes our lives easier and more comfortable	O	O	O	O	O
The benefits of science are greater than the harmful effects	O	O	O	O	O

Meaningfulness of programming (Programming; Source: Kong et al., 2018; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Programming is useful to me	O	O	O	O	O
Programming will help me achieve my goals	O	O	O	O	O
II want to become good at programming	O	O	O	O	O
Programming is important to me	O	O	O	O	O

Impact of programming (Programming; Source: Kong et al., 2018; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I want to use programming to help solve problems in the world	O	O	O	O	O
I want to use programming to make people's lives better	O	O	O	O	O
I can use programming to make daily life easier	O	O	O	O	O

Creative self-efficacy in programming (Programming; Source: Kong et al., 2018; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I would like to design things using programming	O	O	O	O	O
Computer programmers are creative	O	O	O	O	O
It is important to be creative when you are programming	O	O	O	O	O

Programming self-efficacy (Programming; Source: Kong et al., 2018; 5-point Likert scale items, min = 1, max = 5)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I can learn how to program	○	○	○	○	○
I am good at programming	○	○	○	○	○
I think of myself as someone who can program	○	○	○	○	○
I have the skills to program	○	○	○	○	○
I have confidence in my ability to program	○	○	○	○	○

21st century skills (Upper Elementary S-STEM; Source: Unfried et al. 2015)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I can lead others to reach a goal	○	○	○	○	○
I like to help others do their best	○	○	○	○	○
In school and at home, I can do things well	○	○	○	○	○
I try to help other children my age	○	○	○	○	○
When I make decisions, I think about what is good for other people	○	○	○	○	○
When things do not go how I want, I can change my actions for the better	○	○	○	○	○
I can make my own goals for learning	○	○	○	○	○
I can use time wisely when working on my own	○	○	○	○	○
When I have a lot of homework, I can choose what needs to be done first	○	○	○	○	○
I can work well with all students, even if they are different from me	○	○	○	○	○

21st century skills (Middle/High S-STEM; Source: Unfried et al. 2015)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I am confident I can lead others to accomplish a goal	○	○	○	○	○
I am confident I can encourage others to do their best	○	○	○	○	○

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I am confident I can produce high quality work	○	○	○	○	○
I am confident I can respect the differences of my peers	○	○	○	○	○
I am confident I can help my peers	○	○	○	○	○
I am confident I can include others' perspectives when making decisions	○	○	○	○	○
I am confident I can make changes when things do not go as planned	○	○	○	○	○
I am confident I can set my own learning goals	○	○	○	○	○
I am confident I can manage my time wisely when working on my own	○	○	○	○	○
When I have many assignments, I can choose which ones need to be done first	○	○	○	○	○
I am confident I can work well with students from different backgrounds	○	○	○	○	○

TIWI

Teaching ICT with Inquiry

TIWI Teaching ICT with Inquiry introduces the use of coding to upper primary and secondary teachers and to their students. The present publication aims to provide educators and other educational stakeholders with evidence and concrete examples of the suitability and usefulness of teaching ICT through a pedagogical approach based on investigation.

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TIWI WEBSITE

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