TIWI

Teaching ICT with Inquiry

# Intellectual Output 4: Self-assessment questionnaire

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Authors: Tasos Hovardas, Maria Irakleous

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# Contents



# List of tables

## Introduction

Two self-assessment questionnaires have been developed in the frame of TIWI for two target groups: teachers and students. We used 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). These newly developed scales were pilot tested. 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 by project partners.

## Structure and administration

The instruments were administered online to individual respondents via SurveyMonkey as a pre-post test before and after the educational interventions of TIWI in Lithuania, Spain, France and Cyprus. We offered several scales 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 different respondent is able to compile her own version of the instrument, based on her own needs and desires. 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 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 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 1094 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. With regard to 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 equaled 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 | $-1.33^{ns}$ |
| Future participation in science | 0.59 | 0.60 | $-0.34^{ns}$ |
| Meaningfulness of programming | 0.66 | 0.68 | $-1.61^{ns}$ |
| Impact of programming | 0.66 | 0.68 | $-1.68^{ns}$ |
| Creative self-efficacy in programming | 0.71 | 0.71 | $-0.45^{ns}$ |
| 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 presented 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).

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, * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

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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)

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)

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

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)

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)

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)

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)

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)

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)

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)

I can select effective teaching approaches to guide students thinking and learning in STEM

I am aware of the different approaches for teaching STEM

I know pedagogical theories/models that apply to teaching STEM

I know teaching strategies that could be used for improving teaching STEM

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

I can select effective technologies for understanding and doing STEM

I am aware of the different technologies that can be used for understanding and doing STEM

I have been trained to use different technologies that can be used for learning STEM

Several technologies exist for understanding and doing STEM

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

I can choose technologies that enhance the teaching approaches for a lesson

I can choose technologies that enhance students' learning for a lesson

My teacher education program has caused me to think more deeply about how technology could influence the teaching approaches I use in my classroom

I am thinking critically about how to use technology in my classroom

I can adapt the use of the technologies that I am learning about to different teaching activities

I can select technologies to use in my classroom that enhance what I teach, how I teach and what students learn

I can use strategies that combine content, technologies and teaching approaches that I learned about in my coursework in my classroom

I can provide leadership in helping others to coordinate the use of content, technologies and teaching approaches at my school and/or district

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)

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)

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? ($3^{rd}$ to $12^{th}$)

## 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.

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.

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.

What was the dependent or responding variable?

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.

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.
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.
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.
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.

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.
D. Number of tubs receiving rotted leaves.

What is the dependent or responding variable?

A. Amount of tomatoes produced in each tub.
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.
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.

## 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.
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.
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.

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.
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 liter 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.
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.

## 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.
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.
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.
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.

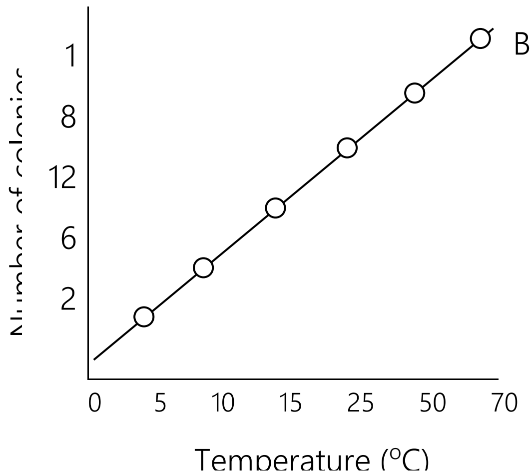
## **Graphing and Interpreting** (TIPSII, Source: Burns et al., 1985)

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

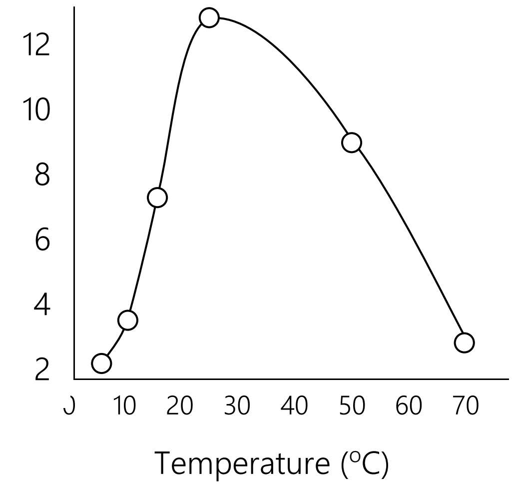
| Temperature of growth chamber (°C) | Number of bacterial colonies |
|---|---|
| 5 | 0 |
| 10 | 2 |
| 15 | 6 |
| 25 | 12 |
| 50 | 8 |
| 70 | 1 |

Which graph correctly represents the data from the experiment?

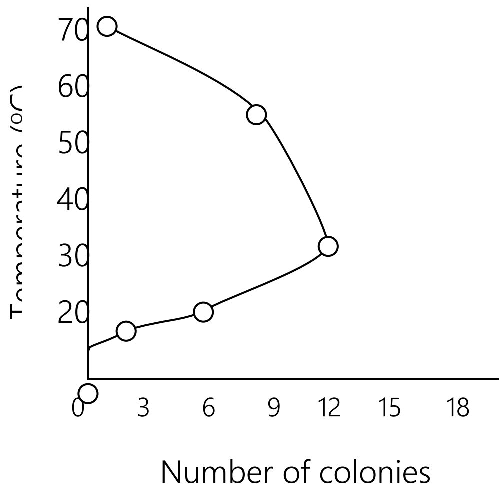
A.



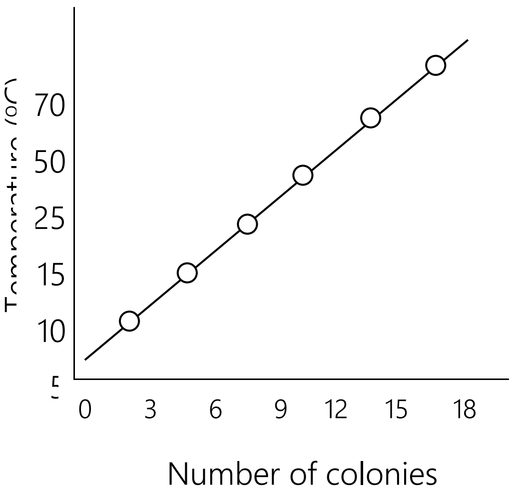

B.



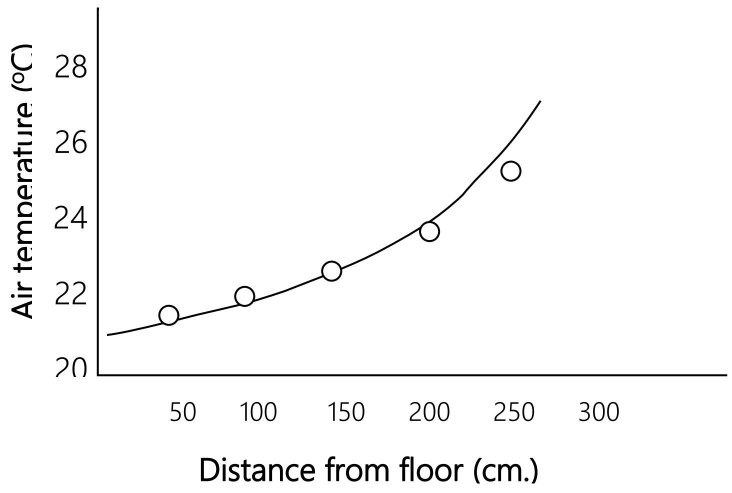

C.




D.



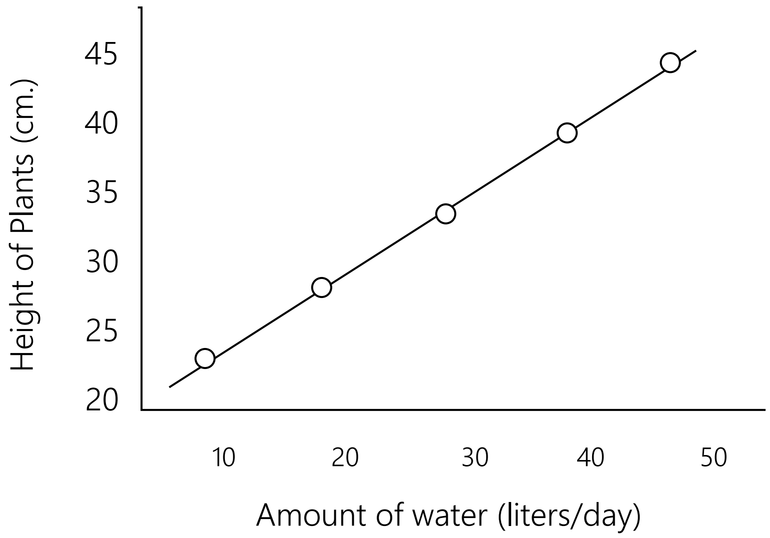
A study is done of the temperature in a room at different distances above the floor. The graph of the data is shown below. How are the variables related?




A. As distance from the floor increases, air temperature decreases.
B. As distance from the floor increases, air temperature increases.
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?

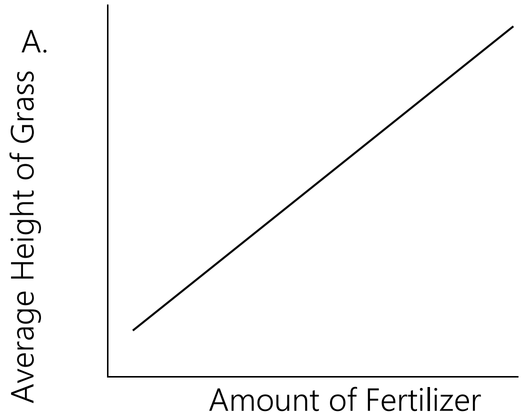
A. Increasing the amount of water increases the height of the plants.
B. Increasing the height of the plants increases the amount of water.
C. Decreasing the amount of water increases the height of the plants.
D. Decreasing the height of the plants decreases the amount of water.

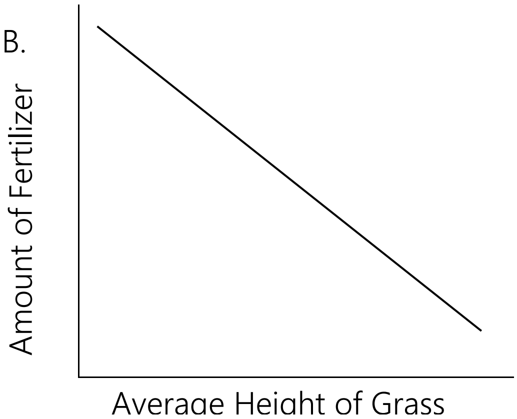



A researcher is testing a new fertilizer. Five small fields of the same size are used. Each field receives a different amount of fertilizer. One month later the average height of the grass in each plot is measured. The measurements are shown in the table below.

| 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?



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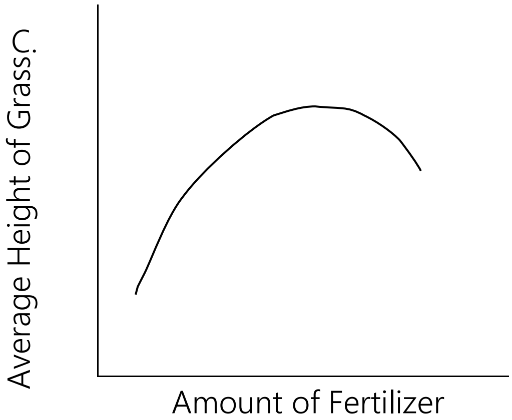


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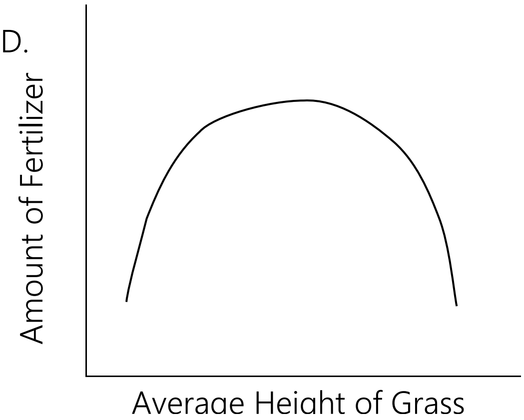
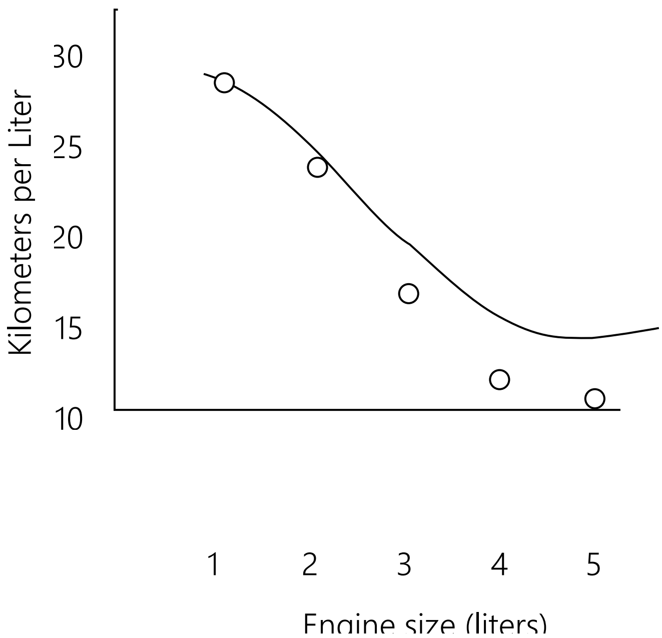



A consumer group measures the miles per gallon cars get with different size engines. The results are as follows:




Which of the following describes the relationship between the variables?

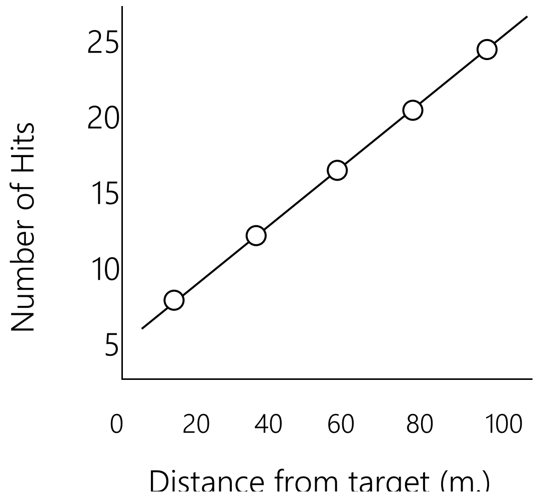
A. The larger the engine the more miles per gallon the car gets.
B. The fewer miles per gallon the car gets the smaller the engine.
C. The smaller the engine the more miles per gallon a car gets.
D. The more miles per gallon for a car the larger the engine.

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.

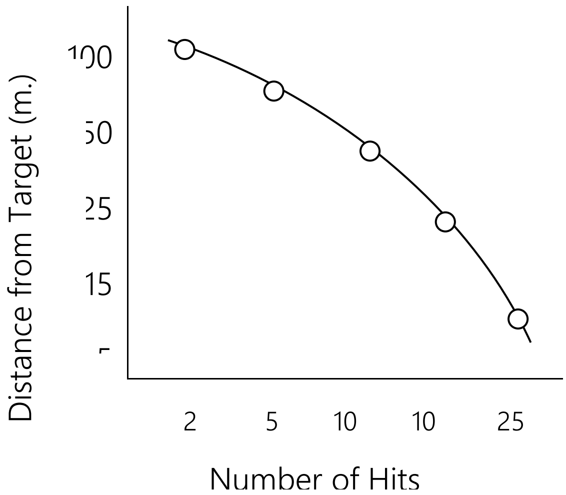
| Distance from Target (m.) | Number of Hits |
|---|---|
| 5 | 25 |
| 15 | 10 |
| 25 | 10 |
| 50 | 5 |
| 100 | 2 |

Which graph best represents the data?

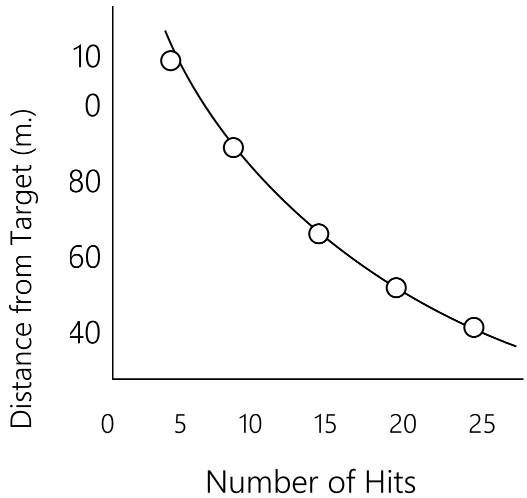
A.



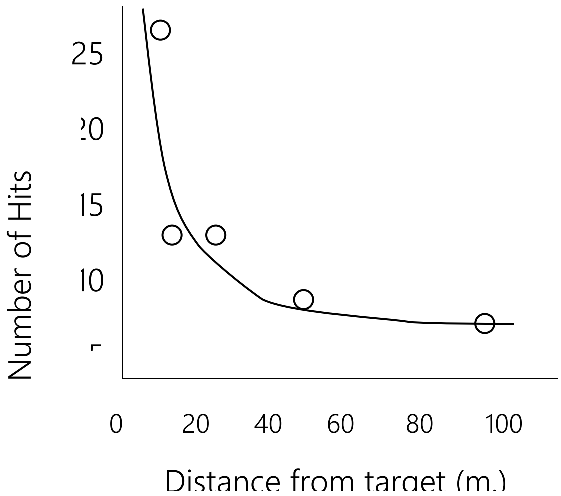

B.




C.




D.




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

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)

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)

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)

Science and technology is important for society

Science and technology makes our lives easier and more comfortable

The benefits of science are greater than the harmful effects

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

Programming is useful to me

Programming will help me achieve my goals

I want to become good at programming

Programming is important to me

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

I want to use programming to help solve problems in the world

I want to use programming to make people's lives better

I can use programming to make daily life easier

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

I would like to design things using programming

Computer programmers are creative

It is important to be creative when you are programming

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

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)

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 respect all children my age even if they are different from me

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)

I am confident I can lead others to accomplish a goal

I am confident I can encourage others to do their best

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