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AN ANALYSIS OF WEB-BASED COLLABORATIVE INQUIRY OF PRIMARY SCHOOL STUDENTS VIA ONLINE STUDY MODE

MA thesis

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Abstract

This thesis presents a study on the inquiry skills improvement of primary school students throughout a web-based collaboration process in groups of two. The study took place in an elementary school in Ukraine. Students of two classes were assigned into heterogeneous teams of two to collaborate in the virtual lab simulation to explore the laws of inheritance. One of the classes had a prior virtual lab experience. The results demonstrated that both classes improved their knowledge with experienced students showing higher results. A focus-group interview found weakened sides of the study: time pressure and inconveniences in communication provided by the virtual lab. Results suggest that the further study may be elaborated on the better virtual condition for a meaningful collaboration.

Keywords: *Collaborative learning, inquiry skills, inquiry-based learning, science education, virtual lab, online learning, educational technology.*

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Introduction

The labor market has been continuously changing over the past decades. While certain types of jobs are in danger of disappearing as a result of being replaced by artificial intelligence, other types of work activities are emerging at an accelerated pace. Experts say that due to these ongoing processes we should rather focus on the needs beyond the subject-specific content to predict the future of occupations available for new generations (Richardson & Tan, 2007; Gawrycka et al., 2019). It is becoming clear that the subject knowledge itself may not be enough for the needs of the future society. On the contrary, employers are seeking candidates with specific soft skills, and thus the latter plays an important role in predicting the labor market of the future generations (Robles, 2012).

Collaborative skills and the ability to work in a team is a crucial skill in the 21st century. Teamwork skills are listed as an independent branch of skills of employability in Conference Board of Canada, 2014. They can be described as one’s ability to be flexible, actively share the knowledge in a team and communicate with people (coworkers, clients etc.) effectively. Teamwork itself does not only support the skill of effective communication between people but also affects one’s overall social skills, positive environment between peers and overall psychological state of a student (Magen-Nagar et al., 2019).

Another important factor to take into account for teachers is the ever-increasing impact of technology on everyday life. Multiple areas of life are being digitized, as it is making life convenient and saves time (for instance, the procedures of applying, learning, voting online). As a result, the importance of digital skills cannot be denied. Even though young students keep receiving their knowledge about technologies rather from other sources than teachers and parents, the necessity of teaching digital literacy is present. The educational system is at a constant update due to the flexibility and changes of the labor market, technological progress and needs they all create.

Modern classrooms are often equipped with electronic devices, some of them are gaining their popularity (laptops and mobile phones) (Bennett & Maton, 2010; Ryan et al., 2021). Even though the debates on the effect of electronic devices on the learning process are ongoing, their usage for the improvement of inquiry-based tasks demonstrates the effectiveness (Siiman et al, 2017). At the same time, collaborative tasks can be used for the awakening the interest in various scientific subjects, as during the last decade we are witnessing the rapid growth of such segments of the labor market as technology-oriented specialists, IT specialists and manufacturers, who are strongly connected to science and STEM education (Raes et al, 2013).

Considering the information mentioned above, it can be summarized that teachers need to work on the effective improvement of the various soft skills of students and modernize their approach to teaching by implementing effective technologies, devices and tools. Consequently, this thesis will focus on the collaborative and inquiry skills of students and on an effective use of digital technologies.

In this research, I address the statements above and conduct the study upon students' collaborative and inquiry skills. The questions I study are:

1. Does an effective collaboration lead to improving, in particular, inquiry skills of primary school learners?
2. What is the influence of a repeated collaborative process on the students' performance in demonstrating inquiry skills?

The thesis contains 5 chapters.

Theoretical overview

Collaborative skills and collaborative learning

Collaborative learning, according to Warsah and colleagues (2021), is "a learning strategy with two or more individuals being cooperatively engaged in a learning process and practice". In this regard, students or teammates within a learning group are able to negotiate and interact to solve problems within a learning process. Collaborative learning is a well-known concept of Educational Technology and is rather an effective way of study. Derived from Vygotsky's concept of a zone of a proximal development, it emphasizes the crucial importance of social processes on one's learning. According to Dillenburg (1999) collaborative learning occurs in a situation with two or more people who learn or attempt to learn together. This should be distinguished from the cooperative learning process, in which each member of a group takes his own responsibility to contribute to a team learning process (Dillenburg et al, 1995). Slavin (1997), on the other hand, describes collaboration as a philosophical concept related to one's lifestyle, the ill-structured knowledge domains; cooperation is described as a well-structured knowledge domain.

Overall, in works of Johnson & Johnson (1996) and Kirschner (2001) it is stated that in order to teach effectively while using the collaborative learning style, it is necessary to maintain the learning process in groups with a small amount of people; other important factors are:

- students' responsibility for their learning;
- shared experience of teaching and learning;
- space for students' reflection upon their learning process;
- "give-and-take" principle of creating social and team skills.

In other words, the collaborative learning process should be designed in a way that the learner will achieve their result with the help of their teammates. The collaboration requires students to share ideas, investigate the problem or task, discuss the opportunities or thoughts in order to achieve the common goal.

In this case we observe the social and cognitive processes. Nunaki and colleagues (2019) stated that collaborative learning improves the metacognitive skills of learners. According to van den Bossche (2006), students involved in collaborative learning processes have mutually shared cognition, which plays a role in learning behaviors and team effectiveness. Teams also have to present interdependence (Laal, 2013), task cohesion and psychological safety in order to study effectively.

A task given for students to work with in collaboration with their peers should be complex enough and require learners to co-construct knowledge to achieve the progress. If a collaborative task could similarly be solved by a single student, the additional demands that stem from collaborating (e.g. having to coordinate and integrate contributions of group members) will outweigh the benefits of collaborative knowledge construction (Kirschner et al., 2011).

On the other hand, Strauß & Rummel (2020) listed other factors that affect the collaboration of the group:

- Forming groups of students. Groups can be formed homogeneously and heterogeneously. In spite of the fact that it is preferred to create heterogeneous groups, a group of less active students may affect the engagement of every participant in the group.
- Creating positive interdependence (for instance, distributing the tasks between the team members in a way that participants' success depends on the other member of their team);

- Teacher's role: an educator may step in the process of collaboration in order to facilitate new discussion, stimulate a new interaction between students.

In case of the factor of forming students' groups, Bellhäuser and colleagues (2019) have demonstrated that students' personal traits, such as extraversion and conscientiousness, may be involved in poor results of the formed homogeneous groups, as extraverts feel uncomfortable in the environment of those who conquer the leadership position. Another finding is that consciousness affected positively on performance and satisfaction within homogeneous groups, however no effect has been detected on time investment. At the same time, if both variables were taken into account, positive effects on heterogeneous groups performance, groups' satisfaction and their time investment were noticed.

In PISA Collaborative problem solving framework (OECD, 2017) they mention student's background as the factor to consider. That is, student's prior knowledge, experience, age and cultural issues (whether the society approves and praises the collaboration with other people, as well as the culture's general attitude of culture towards unfamiliar people in the context of the interaction of individuals in it).

Collaborative skills of students may be improved in various ways. For example, frequent collaboration and team working in a learning process (Long & Meglich, 2013) or let students reflect upon their learning process after each collaboration experience (Hatami, 2015).

Educational technology and collaborative learning

A rapid growth of technologies is one of the reasons for an increasing interest in using techniques with a use of collaborative learning and teamwork. Teachers are actively using technologies in the classroom these days, not to mention novel methodologies that require digital activities, such as online learning and a model of "bring your own device" (Ryan et al., 2021).

There are various ways to use digital tools in order to provide teamwork. Social media have an impact on learning and may affect as a facilitator of learning in teams, according to Ansari and Khan (2020). The authors suggest that higher education students who demonstrate an active participation in collaborative learning through social media show better academic performance. They also mention that digital activities in social media provide some space for participants who experience shyness to talk in public or are introverts.

The usage of mobile technologies in order to provide collaborative activities has increased in recent years. Mobile technologies provide significant advantages for teachers: portability, social interactivity, context sensitivity (Klopfer et al., 2002). They facilitate seamless social interactions, engage students in simulated learning, situated contexts to learn via mobile technologies.

Overall mobile educational tools attracted much attention from educational technologists and researchers (Fu & Hwang, 2018). The authors stressed the importance of researching the effect of mobile collaborative activities on students' self-learning and life-learning, as well as the new perspectives in providing students with authentical and life-related problem cases in order to improve students' collaboration skills.

Another crucial research demonstrated that there is a correlation between students' high levels of collaborative skills and satisfaction in the online study process. Thus, students who achieved higher results in completing teamwork activities were more satisfied with their distance course(s). Another important finding of the study is that pupils with greater levels of collaborative learning have demonstrated higher levels of social presence (So & Brush, 2008). In that research interviews were conducted with graduate students taking at least one online course throughout their study. The analysis report demonstrated critical factors that can potentially influence students' perception of collaborative learning, overall satisfaction and social presence. Among those factors mentioned above are emotional support of both the teacher and the team, course structure and organization and communication at all levels.

Moreover, it is claimed that frequent collaboration in a digital environment improves teamwork and communication (Ubell, 2011). Ability to collaborate within the chats or messages be a crucial factor to pay attention to when it comes to a collaboration with digital tools (Long & Meglich, 2013), as students usually prefer oral discussions to a chat or another written form of communication due to the challenges of it (Blaskovich, 2008).

About inquiry skills and collaborative inquiry learning

Inquiry learning, according to Pedaste et al (2012), can be defined as "a process of discovering new relations, with the learner formulating hypotheses and then testing them by conducting experiments and/or making observations". It is also mentioned that the main goal of inquiry learning is to improve transferable skills needed for stating hypotheses and making discoveries rather than being able to successfully search for novel correlations in the facts, statements and results of scientific processes.

Inquiry skills can be taught and developed in a step-by-step learning environment with regular and transformative activities throughout the study process (Pedaste et al., 2012). This process contains seven learning stages:

- Problem identification (where learners observe the problem, understand an order of the events, identify patterns and make connections);
- Research question formulation (where students demonstrate the knowledge of their understanding of connections and look for the questions that have to be investigated;
- Hypothesis formulation with providing explanations and evidence after observation;
- Experiment planning (a stage that uses previously collected data to provide testable hypothesis and describe the plan of testing one);
- Carrying out an experiment according to a mentioned detailed plan with following the steps;
- Analysis and interpretation of the results (where students show their critical thinking in order to synthesize the collected data and analyze the patterns obtained after a carried experiment;
- Drawing the conclusions and presenting the results.

Inquiry skills are crucial in collaborative inquiry learning, which is a quite modern approach that is widely used in STEM-oriented subjects. The importance of inquiry learning is that it is often widely related to the collaboration process (Bell et al., 2009). Communication is the collaborative element of inquiry learning. Communication is a process that often spans other processes and steps of scientific inquiry. Students learn how to make claims, hypotheses and conclusions out of received data and to reflect their own work. When students work in groups, they share the knowledge with their team members in order to look for patterns, share thoughts and ideas necessary for completing the task. Collaboration scripts is one of the widely used examples of structuring a communication in group discussions (Kollar et al., 2005).

Bell et al (2009) argues that computers support students in such steps of inquiry learning as planning an experiment, discussing and sharing knowledge, proceeding routine tasks (calculating, sorting data, saving information etc.). They mention that because students partly or fully control computers, they are able to avoid the teacher's full guide in tasks as access to information and hints are less limited. Integration of computers and mobile devices are provoking self-regulated learning as well, as a result, positive effects on learning motivation can be provoked.

Inquiry learning has shown a meaningful impact on learning science and STEM-oriented subjects. Several countries with a strong educational system (for instance, Germany and the United States) state the importance of providing the scientific approach of discovering, experimenting and stating and testing the hypotheses throughout the study process in the classroom (Bell et al, 2009). In research of Margunayasa et al (2019) it is demonstrated that there is a clear difference in science learning achievement of elementary school comparing the groups of learners with a guided inquiry learning model to those who were taught through conventional teaching models. The results were explained by an atmosphere created by the inquiry model, which positively affected the development of students' active participation in the learning process.

Aims of the study and research questions

This research is carried out with the sole aim of launching collaborative learning tools that could be used to increase students' inquiry skills and engage primary school learners, and further, examine the general interest of students in STEM-oriented subjects (in particular, biology) of grade 9 students in Ukraine as well as exploring potentials for teaching with digital tools.

The following research questions were addressed:

1. Does an effective collaboration lead to improving, in particular, inquiry skills of primary school learners?
2. What is the influence of a repeated collaborative process on the students' performance in demonstrating inquiry skills?

In the following sections, the methodological approach as well as the study setup is explained. Later on, the analysis and results on findings are presented, followed by a discussion, as well as the limitations and implications of this work.

Methods

For this research a mixed method was used. This is due to the small sample obtained for conducting the research. At the same time, a mixed method will allow us to focus more on the actual students' opinion and experience; to look at the process not only through the statistical point by comparing the results but also to find some concerns and ideas from those who participated in the research.

For the qualitative data collection, the online focus group interview was chosen. As the research was done online via Zoom, there is a certain convenience in using the same platform to obtain the results of the interview through it. The interview was placed right after the online classes. Another necessary factor to receive the interview results via Zoom is the ability to record the interview with Zoom. The platform allows recording meetings, video presentations and the chat of the conference room.

For the quantitative part of the research, several methods were used. First of all, the data was collected from students via Google form prior, during and after the online lessons. This platform allows recording the full answers with a possibility to analyze the results both separately and in total. It is also possible to convert the results into an Excel fine. Secondly, the GRAASP learning platform was used to conduct the lesson and to provide the platform for an online collaboration.

Sampling

Students of two classes from a public school in Dnipro, Ukraine, were chosen to have an experiment. The two classes of grade 9 had 21 and 28 respectively. However, due to the ongoing war in Ukraine, the number of students who fully participated in the project dropped to ten and nine respectively. This is due to the forced leave of the country of the students with their families, inner migration to the less developed and populated settlements with a poor internet connection and other crucial factors.

The sample was chosen because of the Ukrainian curriculum: the students were already familiar with the related topic (that is, basic genetics and laws of inheritance). At this point there was no need of teaching the students the material and the focus was straightly on practicing the received knowledge.

The students' ages are 14 to 15 years old. Class 1 included eight boys and two girls with a total of ten students, whereas class 2 had five boys and four girls with nine students overall.

Instrumentation

GRAASP social learning platform

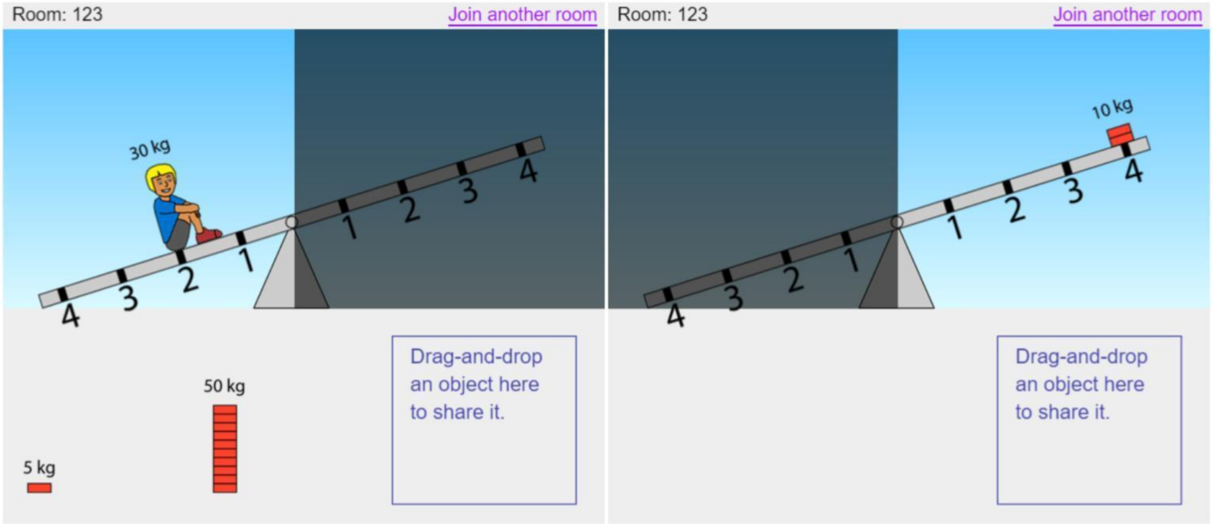
GRAASP is a non-profit organization providing digital education sources and tools. It provides a website (URL: graasp.eu) with a built-in setup with various educational tools and digital labs for an online experience. The platform was chosen for several reasons:

1. Availability: the platform is free to use both for the teachers and the students, convenient in personalizing setting up the labs for your needs;
2. Language preference: the platform is available in various languages, including Ukrainian, which is a language of instruction in a majority of Ukrainian schools.
3. Access: the experimental labs can be used both from the mobile phone and laptops and tablets. This is a factor to make sure those who cannot access the computers at the time the study took place were still able to participate.

For the experiment all the learning materials were translated into Ukrainian. For the experimental procedure, a personal account was created on graasp.eu website, as well as two of the digital labs were used.

Collaborative Seesaw Lab

Collaborative Seesaw Lab (from here – “seesaw lab” or “seesaw activity”) is a virtual lab for two students to work collaboratively at a distance (Figure 1). The lab has two versions for each student in which they have an access to one side of the seesaw and a limited number of objects to put on the seesaw, as the lab is aimed to create a collaborative experience between two students. The partner’s side of the seesaw is invisible and thus the student is unable to control it or predict the actions done on the other side. The two versions are named A and B respectively.



(a). (b).

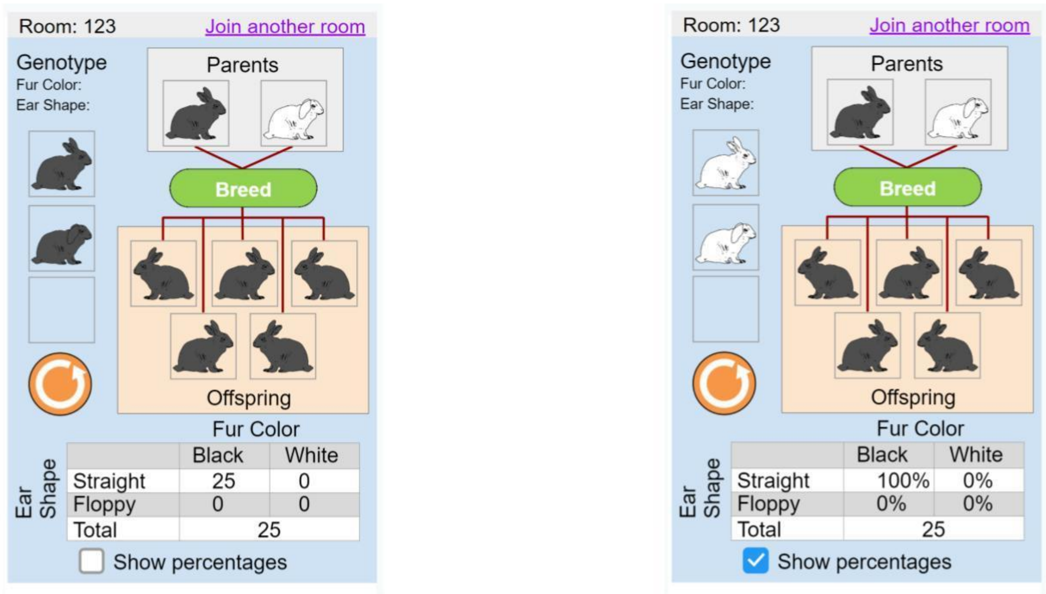
Figure 1. Seesaw lab interface for versions A and B.

The students can log in by using a link on either a mobile phone or a computer. For logging in, the nickname should be mentioned (students were asked to use their real names). The A and B versions are assigned for the students before the log in; at the same time, students connect to the same room by using the same room number.

The seesaw lab, as all the other labs provided by GRAASP, can be edited according to the needs of the teacher. In that way, the input boxes, questions, tasks, descriptions of the tasks, additional materials such as illustrations, links, videos etc. can potentially be attached to the lab either on the same webpage or as an attached page.

Collaborative Rabbit Genetics Lab

Collaborative Rabbit Genetics Lab (from here – “rabbits lab” or “rabbits activity”) is the main lab used for the experiment as it is directly related to the subject taught to students (grade 9 biology). The interface is presented in Figure 2.



(a). (b).

Figure 2. Rabbits lab interface for versions A and B.

The lab is set for two students to collaborate on a distance. The two versions have rabbits with different features and thus, different genotypes. The two features presented in the lab are: the color of the fur (black and white) and the shape of the ears (straight and floppy). Each student has two rabbits on their screen, which are white or black depending on the version they received. At the same time, both participants have one rabbit with straight ears and one with floppy ears. By clicking at either of the rabbits the participant has, the genotype is shown above the rabbits for both characteristics.

The rabbits can be moved to the “parents” gray box. This box is the connection between two partners: as long as any rabbit is moved to the box, both students will see the rabbit on their screen. After pressing the green “breed” button, five random offspring appear in the orange box named “offspring”. Both students can pick any of the offspring to the box on the left to have an additional rabbit to work with. The breed can be canceled by pressing the orange button to restart the experiment. All the rabbits saved above the orange button cannot be removed.

The table below the offspring box demonstrates the statistics of the offspring according to the features (color of the fur for the columns and shape of ears for the lines). The more the "breed" button is pressed, the more offspring are included in the statistics. It can be erased by clicking the restart button.

Another important option of the lab is the ability to show the percentage of the offspring instead of their amount. This can be done by ticking the option "show percentages" below the table.

The log in, the versions usage and the chat usage remain the same as in the seesaw lab. All the additives such as texts, taskbars, videos etc. may be included to the webpage

Experimental setup

The experimental setup consists of four main steps (Figure 3).

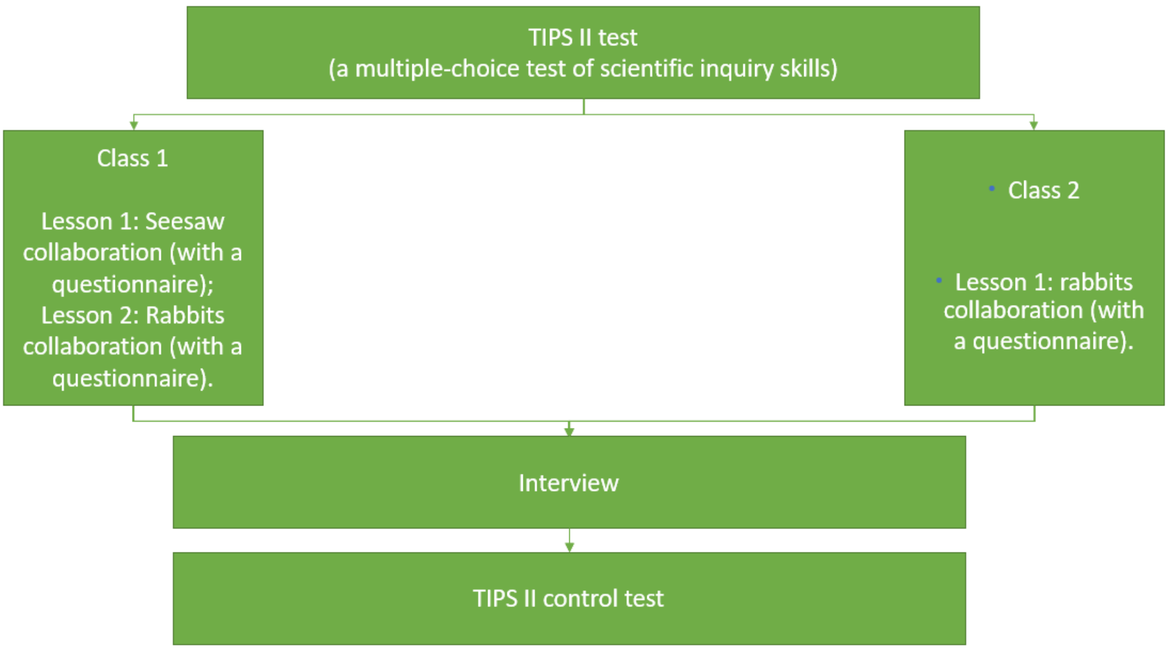


Figure 3. A scheme of the experimental setup.

1. The test of integrated process skills (TIPS) II test is a second, modified version of the test developed in 1980 by Dillashaw and Okey (Burns et al, 1985). The test is a 21 multiple choice questions with one right answer for each question (Appendix 1). The test was translated into Ukrainian and transferred to a Google form for easy access at after school time. The test was provided two weeks before the online classes took place.

2. Online classes to provide collaborative learning experience. Two conditions in this experiment were applied:

- For the class 1 the two lessons were taking place, in which students covered the biology-related rabbits activity with a prior experience of using GRAASP learning environment provided by the seesaw activity. The students received one question within each version in a seesaw simulation and three questions in the rabbits simulation (Appendix 2).
- For class 2 one lesson took place, in which students covered the biology-related rabbits activity whereas the questions remained the same as for the rabbits' activity of class 1.

Regarding the additives to the virtual labs, the chat for providing a written communication was added on the right side of the interface to support the collaboration at a distance. The messages of each participant were saved automatically for a further analysis. For the convenience of analyzing the chat messages, spaces were created for each group of students, which means that students had different links to access the virtual lab.

The input box was added underneath the lab environment for answering a task question. The answers of each student are automatically saved. The overall look for both simulations is demonstrated on Figure 4, 5.

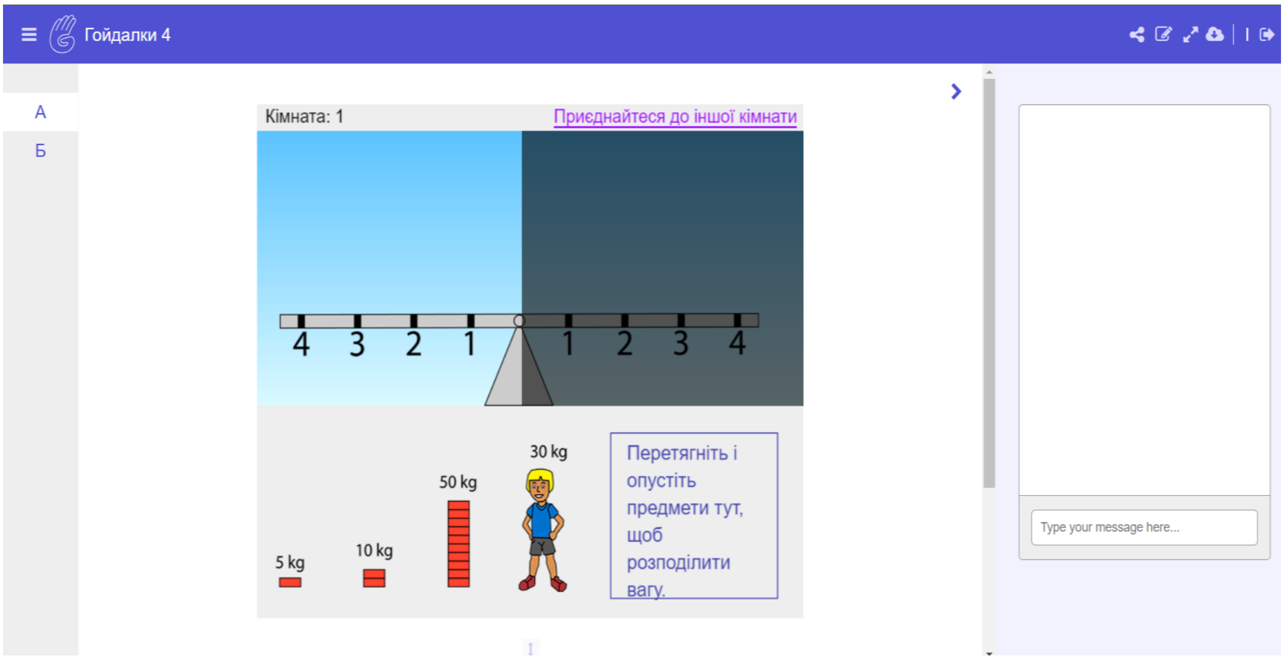


Figure 4. Seesaw lab interface with the chat.

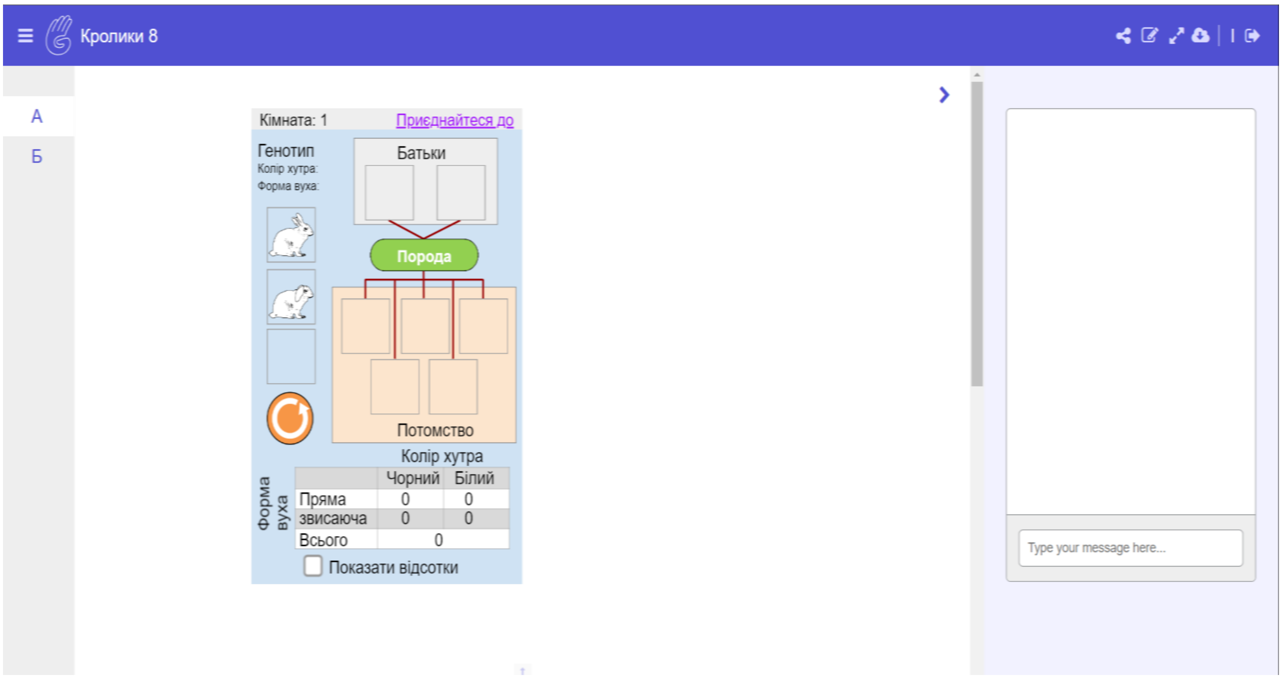


Figure 5. Rabbits lab interface with the chat.

- In both cases a questionnaire (Team Learning Beliefs & Behaviors Questionnaire) (Van den Bossche, 2006) was provided after each of the virtual lab experiences (Appendix 3). The questionnaire contains Likert scales to estimate the participants' behaviors and the interdependence level for each student personally, as well as two open questions to determine the participants' beliefs and concerns towards the collaborative experience they went through.

3. A focus group interview took place for both classes separately. While class 1 was interviewed in week 2 after finishing the rabbits activity on time, class 2 had an extra Zoom meeting on week 2 for completing it.

4. TIPS II control test (from here – control test) is a TIPS II test with a changed question order and changed personal names. The control test was used in order to compare the progress of the students in inquiry skills.

Collaboration was provided by dividing class into heterogeneous pairs of students in a random way. The table in Google sheets was created in order to form the groups and provide students with personal links. Students in pairs worked with versions A or B depending on the link they received. In class 2, one group of 3 students was created in order to involve an odd number of students.

In class 1, the groups were not saved for lesson 2 and new couples were formed using the same procedure.

Data analysis

The data collected from students were not shared to any third party and remains confidential.

For the analysis the following information was received:

- TIPS II test was collected from all the participants and graded with 21 points maximum based on the assumption: 1 point for each correct answer.
- The chat of the virtual labs provided a written conversation occurred between the participants.
- The answers to the tasks for the virtual labs were saved in the input boxes to analyze if the students found the correct answer based on their collaboration experience and prior knowledge of the topic (in case of the rabbits activity, which is strongly based on the knowledge of basic genetic laws);
- The questionnaire presented to students in Google form collected opinions and thoughts after every collaboration experience occurred. Thus, for class 1 it was possible to analyze the dynamics of their collaborative process and changes in their experience.
- The TIPS II control test was compared to the previous results of the students. The score system remained the same.
- Focus interview was semi-structured and occurred online. Data collected through the interview was checked thoroughly for consistency and completeness. It was later transcribed from oral format (recorded videos of Zoom conferences of each class) to text and was subjected to a thorough analysis. For the encoding and transcribing each question and answer, NVIVO software was used. NVIVO made it easy to link different paragraphs from the interview transcript to the theme nodes they correlate with. Such a task would have been a very tedious one if it was done manually.

Results

TIPS II test and responses upon the virtual labs' tasks

As it was mentioned previously, the TIPS II test was used to evaluate students' inquiry skills. It allows students to evaluate student's integrated process skills related to science and meaningful research activities such as stating hypotheses, interpreting graphs, designing fair investigations, and operationally defining variables. The test is not specific to any Science-related curriculum and is interdisciplinary (Burns et al, 1985). The test results are demonstrated in figure 4.

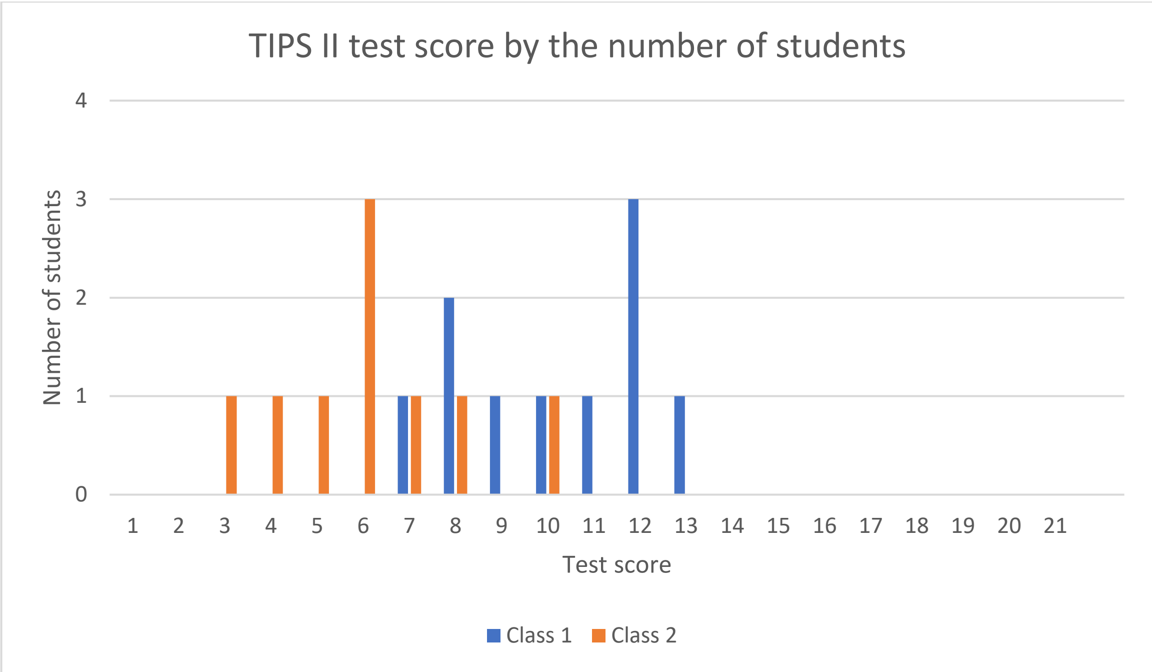


Figure 4. TIPS II test results of class 1.

As it can be seen from the figure 4, the students were mostly not skilled at stating hypotheses and interpreting the results. Surprisingly, no participants showed a result of more than 13 points.

For the seesaw activity, students of class 1 received a prior instruction of the website usage. A PowerPoint presentation was delivered to students with a further investigation of a task given to students. The idea that was carried during the experiment was to provide students with different tasks to research. Thus, students conducting an activity originally had to figure out that their questions are slightly different through collaboration and an active conversation in a virtual chat.

Out of the four groups that participated in an activity, three answered the questions correctly. One group has clearly shown the lack of a collaboration as one person did not follow the instructions and did not describe the solution to the problem but rather stated that the seesaw is possible to balance. Their groupmate did not answer the question.

During the second session of class 1, instructions for the rabbits activity were delivered. The presentation was focused on inquiry skills and the statements related to planning an experiment (such as “dependent variable” and “independent variable”). There were also mentions of the examples of task questions in order to overcome the time pressure for students. Overall, each student had three questions to complete. As I checked the task completion, it was found that out of 30 recordings of answers, three were correct. Most of the students could not complete biology-oriented questions rather than a question about identifying variables.

For class 2, the procedure of an online class was the same as for the second session of class 1. It is seen that out of 24 recorded answers, two were correct, ten were partially correct. Eight students left the last question empty. Here, on the opposite, students showed more knowledge of the topic rather than the one related to inquiry skills.

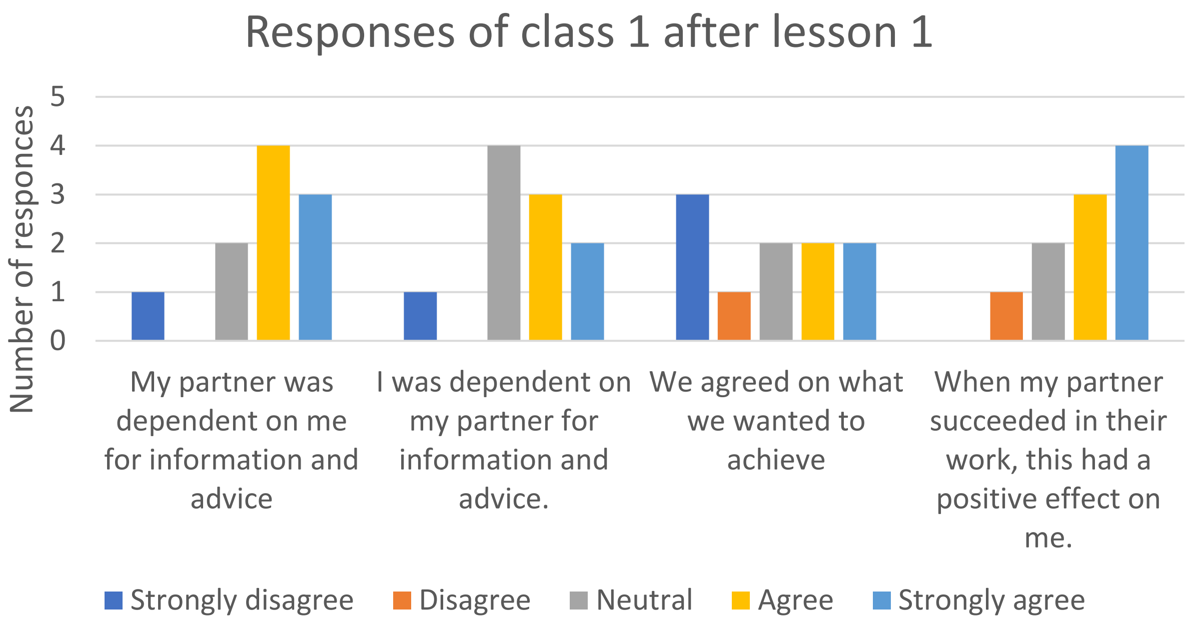
The average score for the tasks provided by Collaboration rabbit genetics lab are distributed in a Table 1.

Table 1. Average score (%) on the Rabbits activity questions

Question	Class 1	Class 2
1	38.25	43
2	20	25
3	1.25	4

Questionnaire responses

The next data extracted from the online lessons was students’ answers from questionnaires aimed to reflect on their collaborative skills. The responses of questions with Likert scales are demonstrated in Figure 5, 6 for class 1 and 2 respectively.



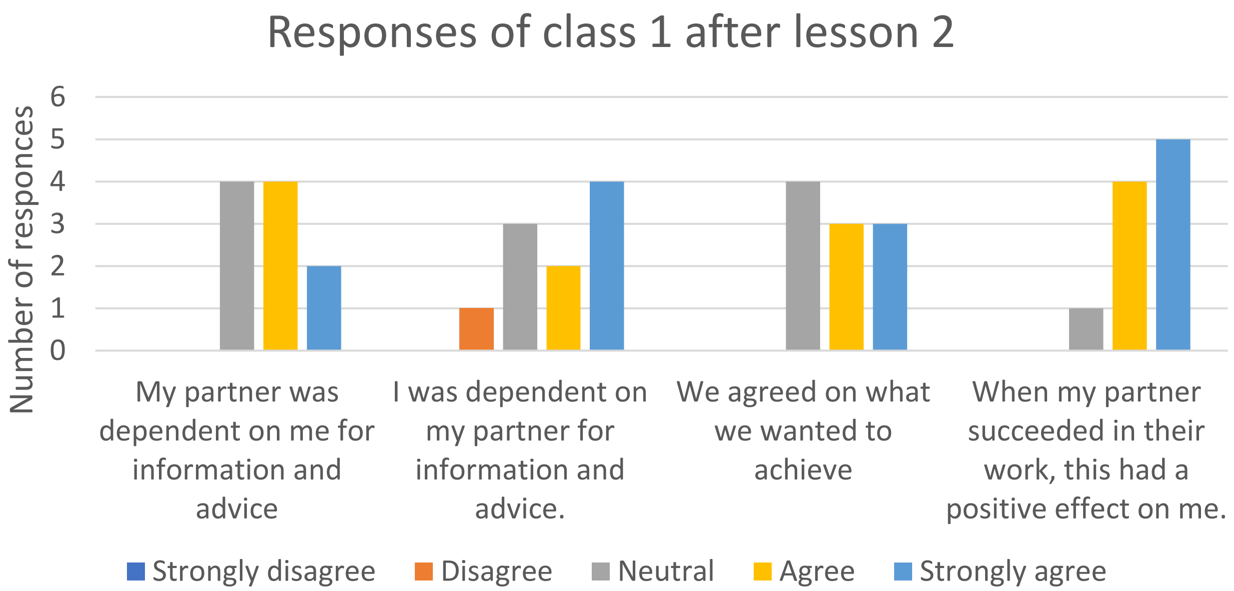


Figure 5. Charts of questionnaire responses from class 1.

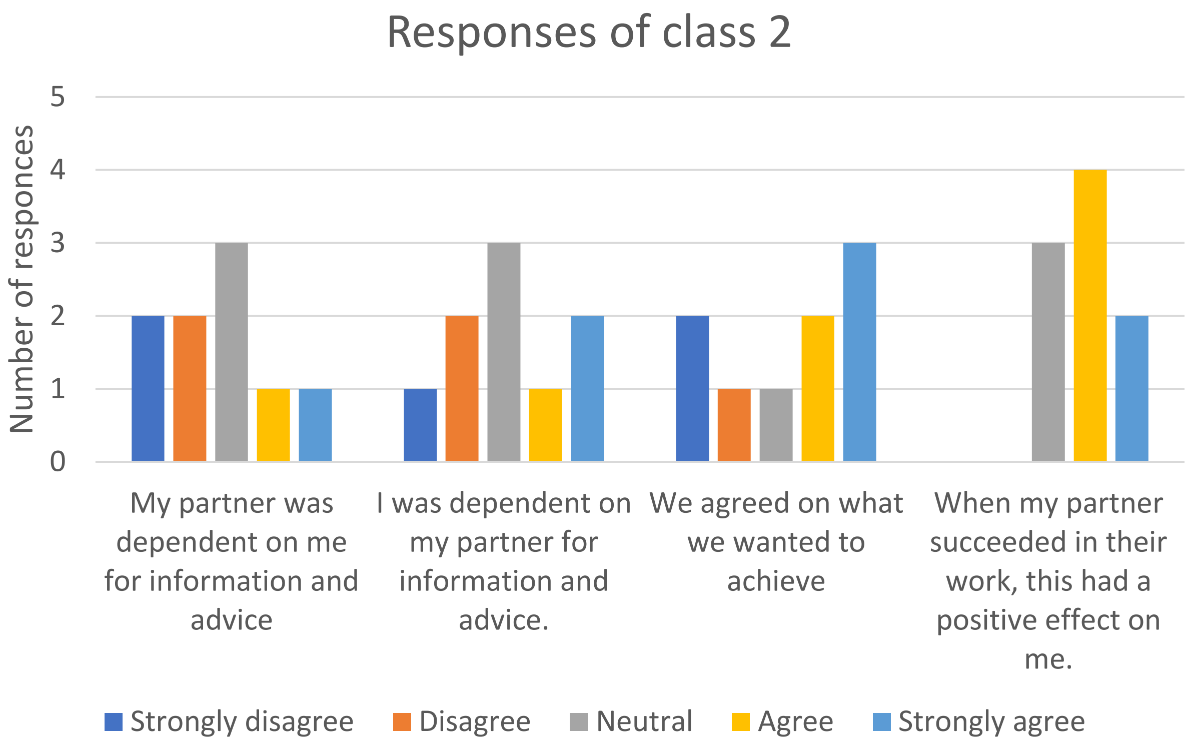


Figure 6. Chart of questionnaire responses from class 2.

It is a clear change of responses of class 1 students after the second lesson. For instance, there were no students who claimed that they disagreed with each other about their goals while collaborating. Also, with one exception students tended to agree that either them or their partner experienced some dependance on each other while collaborating in a rabbits virtual lab, whereas in the seesaw lab some students claimed that they worked quite independently.

Another piece of data to be examined is the open question of the collaborative questionnaire. Overall, 24 responses were received to look for the patterns when it comes to collaborative experience of the students.

For question 1, “What was the most difficult for you in this collaboration? Why?”, students provided short answers, the main ideas explained were:

- to understand how the simulation works;
- to agree with my partner on the decision;
- to answer the question(s);
- time pressure;
- the chat usage;
- nothing.

After the seesaw experience, the student from class 1 who appeared to be the third partner, explained:

I was the third in my team, so the most difficult task for me was to understand how to cooperate effectively with other students.

The time pressure complaints were noticeable after the rabbits activity. Both class 1 and class 2 students experienced the same feelings about the lack of time to figure out all three questions of the virtual lab. Some of the students simply noted that the most complicated part of the task was to understand how to achieve the result that was planned originally and how to get the rabbit with a specific genotype from this virtual lab.

Other students described the problems with answering the questions, but according to the responses it can be concluded that these difficulties were once again related to the rabbits virtual lab.

There were three answers concluding that the responders did not have any difficulties and all of them belonged to class 2 students who happened to show little collaboration with their peers and possibly little interest in the activity. Those students were rather unwilling to talk or discuss anything during the interview. Another similar response was from the student of class 1 after his second collaboration experience, where he stated that after the second try there are less limitations for him in understanding the principles of collaboration:

After the second game I don't feel any difficulties like those ones I had in the beginning.

The second open question left in the students' questionnaire was the following: "What do you think is important for collaboration to be successful?". The students responded rather briefly and provided the thoughts that can be divided into the next categories:

- A friendly way of talk;
- A fast transfer of information;
- To listen to your partner's ideas and thoughts;
- Communication;
- Friendship between partners;
- Understanding of the topic;
- Respect to others;
- Ability to listen and do what people ask you to do;
- Ability to negotiate.

According to one student:

It is important to understand what our task is, and that's why it is important to communicate properly and to find the answer quickly through the proper discussion.

Another student talked about a self-management being a part of the successful cooperation:

You must have confidence in your actions, respect the opinions of others, and also plan everything.

Interestingly, in class 1 students tended to elaborate on their answers rather than change their opinion. For instance, a student noted after the seesaw activity:

In a collaboration process it is important to be able to negotiate.

The response of the same student after the rabbits activity was:

It is important to negotiate with your partner quickly and effectively.

Overall, it can be concluded that students generally understand the process of collaboration and are able to identify key factors that influence the overall group's unity and solidarity with each other. Mostly the students have demonstrated the correlation of the views upon the collaboration in general and their personal experience in particular.

Chat analysis and focus group interview

The chat was analyzed for inspecting the collaboration process between the students. Due to the lack of data to analyze, the focus was on the types of collaborative problem-solving skills students used in their discussions according to the PISA collaborative problem-solving framework (OECD, 2017).

Out of five groups of class 1, one ignored the chat when participating in the seesaw activity. Another group used the chat for confirming the result and did not record any discussion upon the procedure of solving the task. While examining the chats of the rabbits activity, the same pattern occurred, however the second group ignored the chat as well.

In class 2, who had one chance of using the platform, out of four collaboration groups two used the chat for confirming their presence in the lab while others left the chat empty.

In class 1, the following skills were present:

- C1: communicating with the team members about the actions being performed. Students of class 1 were capable of discussing the actions before them being done. This is proven by using the phrases like: "Let's move [the object] to [the place]" and "What about [completing the action]?".

- C2: enacting plans: students of class 1 tend to follow each other's ideas. They either confirmed their agreement upon plans or thoughts shared before or discussed the results of enacted steps straight away, which is undoubtedly a sign of an action being completed.
- C3: following rules of engagement: (e.g. prompting other team members to perform their tasks): it can be concluded from the chats that students cooperated by helping each other and hinting on the steps that should have been done. For instance, in one of the chats the students were describing the specific objects that have to be moved or replaced.
- D1: monitoring and repairing a shared understanding: in one of the chat students discussed the tasks they have. By that time they found out that their questions were different. The following dialogue occurred:

Student A: wait. Put the 50 [kg block] back

Student B: we have to have 2 [objects] on the seesaw, why [should I] put it back?

Student A: why 2? It's 3

Student B: I don't get it. What's your question?

This can be considered as repairing a shared understanding of the problem students appeared to have.

- The kind of conversation mentioned above can also be identified as B2: identifying and describing tasks to be completed. Notably, during the second lesson while working in the rabbits simulation, students of the same groups discussed their questions before moving on to the collaboration process.

On the whole, students demonstrated their openness in collaborating with each other, politeness and ability to participate in a meaningful conversation. Students shared their positive emotions after completing the tasks.

At the same time, it is noted that in the chat conversation of class 2 with the three students some problems occurred. Students were confused with the process and constantly asked each other questions like: "Who's moving this [object]?" or "Let's please not touch this everyone". Considering the specifics of a language, the latter may be seen as a command voice.

Later when the interview occurred, students were asked to explain their ignorance of the chat first. Most of the students replied they were using other social platforms to collaborate. From the student's reply:

I was using Telegram <...> because it is more comfortable for me to focus on the task <...> My telegram was opened on the phone and I used that chat to type there and remain the screen stable.

From the response of another student:

I used the tablet to access the virtual lab, so like every time I wanted to type, my screen was adjusted so that the keyboard appeared. It's not very convenient to move the lab back and forth.

Interestingly, one student mentioned the oral communication to be more reliable when working in groups:

I also used Telegram because me and my partner were using the voice messages to save some time. Well, it is faster to say something rather than type it.

Notably, two students of the same group from class 2 mentioned they haven't used any chat at all and basically experienced no collaboration. They both were not very talkative throughout the interview, and this factor may also be counted when it comes to collaborating with teammates, however they both agreed on them being too concentrated on their own questions. One of them explained:

I was just too focused on my questions and used a (school) textbook to search for the answer.

Meanwhile his partner was looking for help from his elder sibling. But since it was impossible to control the whole system by yourself, the classmates cooperated on social media later.

Another reason the students mentioned about Telegram is that they texted their partners to confirm whether or not they entered the virtual lab. A class 1 student explained:

I noticed there was no way to check <…> if the person is online. The chat was empty for like a minute or so, and I checked the table with our names, found (partner's name) and sent him a message.

Overall, all of the students agreed on Telegram being used as an alternative to the chat of the virtual lab. This may be due to the fact that the students are used to communicating there on a daily basis.

Since a few students discussed voice messages, it was important to collect some information about whether they prefer an oral discussion to the text one. Generally, students agree with oral communication to be faster and clearer. A class 2 student replied:

If we had a chance to speak to each other it would save us time.

Afterwards, the interview part continued with a question: "What did you learn from this collaboration experience you had?". Other questions were elaborated upon the answers of the students.

In general, students reacted to the activity in a positive way. A few people mentioned that the virtual lab experience is a good approach to review the material in a visualized way. For instance, the student from class 1 commented:

I didn't expect our first exercise to be <…> with a seesaw because, well, it's not biology <…>, but we learned it before in a physics (course), I was trying to restore some information about it <…> visually I can recall that.

His classmate stated:

Yes <…> I can recall something, but it <…> doesn't help much when we <…> have 40 minutes to finish (the task), so <…> we worked on the task and not on the physics laws. But anyway, I learned how to work in pairs.

Most of the students' answers were focused on their experience with GRASP rather than on a collaboration process in general. Therefore, there was a decision to ask the students to talk more about their experience in general.

In particular, students mentioned the trickiness of the tasks. The student of class 1 responded:

We were <…> surprised when <…> our questions for the seesaw (activity) were different and I asked you about this <…> usually it happens when there's a typo, so we tell this to our teachers. But I understand now that it is meant to be like that <…>.

Another class 1 student commented:

For me the most difficult part was to control the system <…> to switch the objects with (partner's name) and place them <…> because I <…> think about where she will put her object and try to understand what I should do.

Also, the majority of students mentioned the time pressure. From the response of class 1 student:

I knew that we would have to do something after we wrote down the answer and I thought we would be late, so we tried to hurry up.

The comments about the lack of time were especially related to the rabbits activity. Both class 1 and class 2 students share thoughts about the questions being difficult for a 40-minutes time limit. Class 2 student mentioned:

It <…> took some time to try it out, to try to move the rabbits around <…> to listen to your explanation of the lesson and to register, so we actually had less than 30 minutes to answer <…> actually even less because <…> we had to fill in the form afterwards, it was challenging.

For the class 1, who expected to have a similar task, an increased number of questions was an unexpected situation. From the response of the student:

I know now that we have to double-check the questions with my partner, because we remember <…>the questions may be a bit different, but <…> three questions was kind of a lot. And <…> the task with rabbits is more complicated than the seesaw one.

One of the students claimed that he made a screenshot of the questions and sent it to his partner in order to save time, and so did his partner.

It was also discussed whether the students found a common language with their partners. Everyone agreed that they experienced no problems with discussing, cooperating and proceeding through the task with their peers. A class 1 student claimed:

I remember I asked you whether I could be in a group with (friend's name), but it's just because he's my friend, but of course I worked well with my other classmate. I have no problem with that.

Generally, students confirmed their impression from the activity is rather positive. Students mentioned the key factors that should be changed in order to focus on the task so that the study material is fully delivered. Students confirmed they would be happy to collaborate in the future with the same method.

TIPS II control test

In order to check whether students have improved their inquiry skills, the control test was provided to students after the interview. The results are delivered in a chart form for class 1 and class 2 (Figure 7).

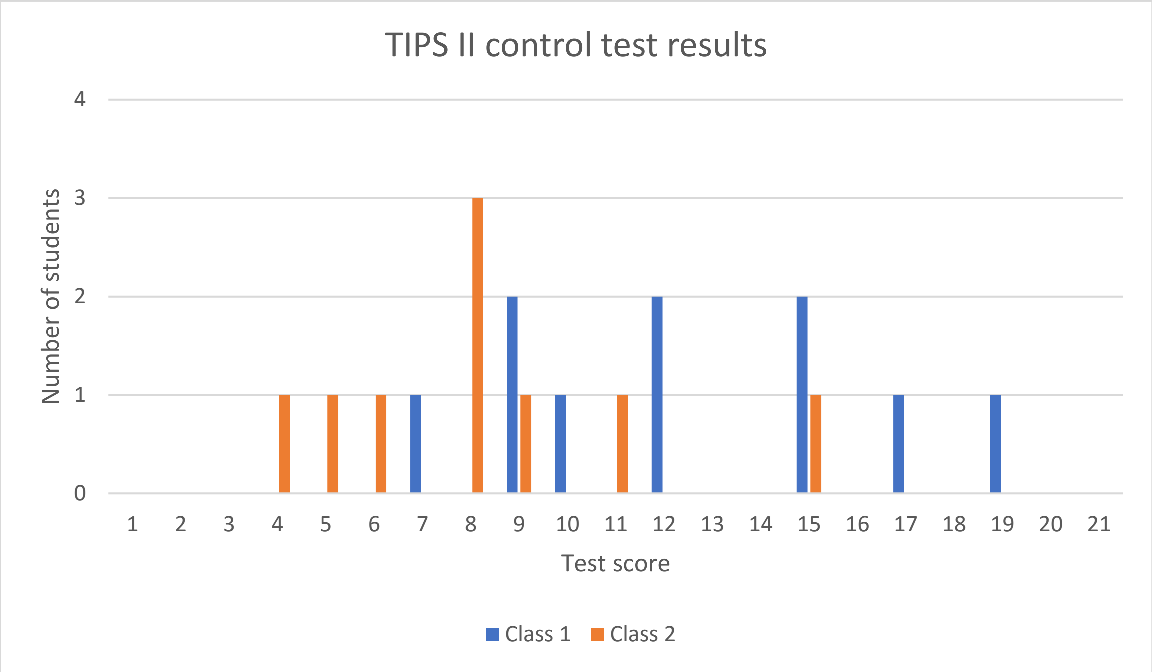


Figure 7. TIPS II control test results of class 1.

From the chart we can conclude that overall, the students improved their inquiry skills, which is especially clear with the results of class 1. It can be explained due to them having more classes and thus time to practice and learn about basic scientific skills like identifying variables, stating hypotheses and conducting an experiment with a full step-by-step description of the process.

To compare the results of the classes, as well as to provide the statistical data upon the results of pre-test and post-test, the classes average results were calculated. It appears that both classes have increased their inquiry skills level, as well as most of the students have increased their results in the test. It is notable that the class 1 overall results were slightly higher than those of class 2. The comparison of the results is demonstrated in Table 2.

Table 2. Pre-test and post-test results of each student.

Class 1 students, #	Pretest result	Posttest result	Class 2 students, #	Pretest result	Posttest result
1	9	9	1	3	8
2	12	12	2	6	9
3	12	12	3	5	4
4	12	17	4	6	11
5	13	15	5	4	6
6	10	19	6	7	8
7	7	7	7	8	8
8	11	15	8	6	5
9	8	10	9	10	15
10	8	9			
Class 1 average result	**10.2**	**12.5**	Class 2 average result	**6.1**	**8.2**

The T-value was calculated for independent and dependent means. The significance level remained as p< .05 for all the calculations, as well as the hypothesis applied was one-tailed.

A paired samples *t*-test was performed to compare the means of test scores of students in the same group before and after experimental learning.

There *was* a significant difference in test scores for group 1 before and after experimental learning:

before: (M = 10.20, SD = 2.10) and after: (M = 12.50, SD = 3.89);

t(9) = 2.4690, The two-tailed P value equals 0.0356.

By conventional criteria, this difference is considered to be statistically significant.

There was a significant difference in test scores for group 2 before and after experimental learning:

before: (M = 6.11, SD = 2.09) and after: (M = 8.22, SD = 3.31);

t(8) = 2.5111, The two-tailed P value equals 0.0363.

By conventional criteria, this difference is considered to be statistically significant.

An unpaired sample *t*-test was performed to compare the means of test scores of students in different groups - group 1 and group 2.

There *was* a significant difference in the means of test scores before the experimental learning between class 1 (M = [10.20], SD = [2.10]) and class 2 (M = [6.11], SD = [2.09]); t(17) = [4.2514], p = [0.0005].

By conventional criteria, this difference is considered to be statistically significant.

There *was* a significant difference in the means of test scores after the experimental learning between class 1 (M = [12.50], SD = [3.89]) and class 2 (M = [8.22], SD = [3.31]); t(17) = [2.5645], p = [0.0201].

By conventional criteria, this difference is considered to be statistically significant.

Discussion

Throughout the research, the data focused on students' inquiry and collaborative skills was collected. The online lessons were provided with various tasks to evaluate the grade 9 students' knowledge of the subject and various skills and abilities such as: collaborative learning, problem-solving, inquiry skills, ability to state hypothesis and identify variables of an experimental setup and providing a meaningful experiment to prove the hypothesis. The findings in this study are interpreted based on the research questions earlier highlighted and established from both qualitative and quantitative data. For further clarity, this interpretation will be done within the context of the research questions for this study.

Research question 1

To answer whether an effective collaboration leads to an improvement of inquiry skills of primary school learners, TIPS II test of identifying variables was used as a pre- and post-test to observe the dynamics of an improvement of the classes in general and each student in particular. From Table 2, we can conclude that the majority of students improved their test results after practicing identifying dependent and independent variables using the examples of virtual labs. Although two students of class 2 dropped points at a post-test, the difference with a pre-test was insignificant and can be explained as a human factor.

To focus on this question, the interview was used as well. As a self-assessment is an effective way of evaluation of the skills of the students as well as a useful method to improve one's abilities, predict the further behavior and to plan to achieve better results; it is also a way to reflect on the work one has done, find mistakes and notice the positive sides or skills (Hatami, 2015).

Throughout the interview, most of the students shared their positive experience in working in pairs. There was a correlation between the active participants of the interview and the post-test results. In particular, a researcher noticed high scores of students of class 1 who actively asked questions when at online class and who provided rather extensive answers at the interview part of a research. On the contrary, those students who did not respond much have demonstrated little or no improvement in the TIPS II test.

At the same time, the lack of data of conversations in virtual lab chats may have led to the question not being fully answered due to the lack of information about how the students proceeded through the collaboration process. Although the students have shown the collaboration problem-solving skills, the picture of the collaboration of different groups is incomplete. In case the students have failed in communicating effectively, it may be another factor that influenced their time pressure and has not led to an effective time management. There may be more effective ways to prepare students to work in groups virtually, such as: providing more short-term virtual and game-based projects (Long & Meglich, 2013). The latter authors also mention that the students have to have strong written communication skills, which the students of the sample may not have had as this experimental setup was the first digital collaboration project they have had.

It is also common for participants to experience challenges in a written form of collaboration compared to the one occurring face-to-face (Blaskovich, 2008). When providing students with a virtual collaboration on a frequent basis, not only will the digital skills and written communication be improved, but also the ability of working in a team in real-life situations (Ubell, 2011).

Research question 2

What is the influence of a repeated collaborative process on the students' performance in demonstrating inquiry skills? It may be concluded from the results of class 1 that the recurring collaboration process leads to the better results in improving the inquiry skills. This can be concluded from the questionnaire results with a Likert scale and the interview. In general, students of class 1 have highlighted their experience in the second session being different from the first one. The reason for that is the students have already had some expectations for the rabbits activity and were prepared for situations when the tasks may differ for each of the team members. More students concluded that during the second class they felt more connection and more of a dependence on their peers, which is undoubtedly a sign of an interdependence in collaborative learning (Laal, 2013).

According to the T-test result, all of the variables extracted from data have shown a significant result of p-value. As for the independent means, it can be concluded that the two classes have different levels of knowledge. However, the difference for the post-test has slightly decreased, and this can be interpreted as the fact that class 2, despite attending one session instead of two, have demonstrated the bigger progress.

At the same time, the dependent mean of class 1 is slightly lower than the one of class 2. In spite of that, both groups have achieved a statistically valuable progress in inquiry skills. Notably, the researchers state collaborative learning to improve metacognitive and inquiry skills and students do demonstrate an improvement of understanding of how to evaluate and analyze alternative solutions for the problem (Nunaki et al., 2019).

Limitations of the study

The main weakness of the study was the number of participants in the study. Due to the external factors not all the students of the school were able to continue their study both remotely and on campus in Ukraine. Additionally, this study was carried out in only one school and based on the experience of total 19 students, which may not be enough to represent the Ukrainian population adequately and may produce biased statistics. or for the students of the same age range as those who participated in the study.

Also, the general limitation of the lack of data being received by the researcher. The limit of the chat data to analyze may not fully present the students' communication and collaboration skills. This was due to the fact that students preferred different ways of communication from those provided by the design of the experiment. The methods of communications hugely depend on personal preferences of students and may differ drastically between generations, however each generation is unlikely to become more productive if forced to change their communication channels, as their habits have already developed.

Furthermore, the methods of online communication differ drastically from personal oral communication. It is clearly seen that face-to-face oral communication in the working environment differs from any possible simulations where students have more time for answering and students usually answer with more freedom than they would in real life situations. It is remarkable that during the interview a lot of students mentioned that they used voice messages in the social media to communicate, which were notably absent at the experiment.

Another limitation of the study was a qualitative analysis that may have been affected by the human factor: for example, the grading process of the student, regarding their answers to the open-style questions. By no means it is possible to evaluate answers to such questions in a completely objective manner. On the other hand, a lack of connection between the students and the interviewer may have impacted the openness of the interviewees to some extent, as it may have happened with the Class #2 where a few students apparently did not feel comfortable answering questions and were apparently closed to communication. It was also noticed that some students were more keen on answering the asked questions via the Zoom chat, rather than the video-conference with their microphone turned on.

At last, the author assumes that the limit of the class time in an online class affects the students' overall state, concentration on the task and annoyance with external factors, which may have impacted the objectivity of the gathered results.

Directions of a further study

As the study has found some weakened spots in the experimental setup, it would be necessary to take them into account when planning and conducting further research in this area. That is, the author suggests that, first of all, the approach to providing students with a platform which they would not like to use and which has some drawbacks in terms of its convenience should be denied. On the contrary, allowing students to use the methods of communication they choose may lead to a better communication process and an effective time management. Moreover, the freedom of choice may be assumed as a positive experience of learning and may hypothetically catch the students' interest in participating in virtual collaborative learning.

Simultaneously, providing students with more time to solve the tasks of the simulation may reduce the students' anxiety and let them concentrate and finish the assignment within the limited time avoiding the time pressure issues.

As mentioned before, students happen to give short answers or avoid the interview process because of different factors, including shyness. This should be solved in a further study. One of the ways to solve it is to give each student a time to think of an answer for their interview questions and distribute the interview time for each student equally. That means that each student has to discuss the interview question and provide an answer within the minimum fixed duration of the answer (for instance, one minute). Another way to receive more answers from students would be to have personal interviews instead of the one for the whole class. This may reduce the pressure of talking in public.

The author assumes the more diverse data should be provided for an analysis in terms of a number of participators. To solve this issue, more schools may be involved in a study in order to receive a wider perspective of the students of the same age.

The author may suggest alternative experimental setups to research the effectiveness of collaboration in various environments. For instance, one can implement the virtual lab experience in the classroom to let the students collaborate while having a live discussion. That may bring other advantages for a researcher, such as the paper forms of a questionnaire and virtual simulation tasks being printed. At the end, the teacher would make sure all the students would finish their tasks in time. Similarly, the researcher may notice more factors and record more statements from the students, analyzing each one's behavior in the classroom. This can be done by recording the class in the classroom or each of the group separately. Likewise, the focus-group interview may take place in the classroom, which may affect the students' answers and let them be more open-minded and debating.

Finally, it is important to bear in mind that the students were already generally familiar with the main topic of the lesson and that the main collaborative simulation provided for both groups were rather used as a tool to review the study material. The author suggests that the results upon the collaborative tasks provided by the virtual labs may be quite different in case of an opposite scenario where it would be used while learning about the basic genetic laws for the first time.

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Author's declaration

I hereby declare that I have written this thesis independently and that all contributions other authors and supporters have been referenced. The thesis has been written in accordance with the requirements for graduation theses of the Institute of Education of the University of Tartu and is in compliance with good academic practices.

03.06.2022

Signature  Date

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Appendix 1. TIPS II test

1. 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 and supplements taken each day.

B. Amount of lifting exercises done each day.

C. Amount of time spent doing exercises.

D. All of the above.

2. A car manufacturer wants to make cars cheaper to operate. They are studying variables that may affect the number of kilometers per liter that cars get. Which variable is likely to affect the number of kilometers per liter?

A. Weight of the car.

B. Size of the engine.

C. Color of the car.

D. Both A and B.

3. 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. If an object is dropped further, then it will fall faster.

B. If an object is higher in the air, then it will fall faster.

C. If the pieces of gravel in a bag are larger, then it will fall faster.

D. If an object is heavier, then it will fall to the ground faster.

4. A police chief is concerned about reducing the speed of cars. He thinks several factors may affect automobile speed.

Which of the following is a hypothesis he could test about how fast people drive?

A. If the drivers are younger, then they are likely to drive faster.

B. If the number of cars involved in an accident is larger, then it will be less likely for people that are to get hurt.

C. If more policemen are on patrol, then the number of car accidents will be fewer.

D. If the cars are older, then they are likely to be in more accidents.

5. 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. If the amount of fertilizer is greater, then the amount of corn produced will be larger.

B. If the amount of corn is greater, then the profits for the year will be larger.

C. If the amount of rainfall increases, then the fertilizer will be more effective.

D. If the amount of corn produced increases, then the cost of production will increase.

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.

6. 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.

D. Different amounts of sunlight are received at different times of the day.

7. 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.

8. 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.

9. 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.

10. 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.

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^{o}C, one at 50^{o}C, one at 75^{o}C, and one at 95^{o}C. He then dissolved as much sugar as he could in each jar by stirring.

11. What is the hypothesis being tested?

A. If the amount of stirring is greater, then the amount of sugar dissolved will be greater.

B. If the amount of sugar dissolved is greater, then the liquid will be sweeter.

C. If the temperature is higher, then the amount of sugar dissolved will be greater.

D. If the amount of water used is greater, then the temperature will be higher.

12. 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.

13. 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.

14. 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.

15. 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. If the amount of sugar is larger then more water is required to dissolve it.

B. If the water is colder than it has to be stirred faster to dissolve.

C. If the water is warmer then more sugar will dissolve.

D. If the water is warmer than it takes the sugar more time to dissolve.

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.

16. What is the hypothesis being tested?

A. If the amount of sunshine is greater, then the amount of tomatoes produced will be greater.

B. If the tub is larger, then the amount of leaves added will be greater.

C. If the amount of water added is greater, then the leaves in the tubs will rot faster.

D. If the amount of leaves added is greater, then the amount of tomatoes produced will be greater.

17. 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.

18. 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.

19. 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.

20. 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. If you feed fish more, then the fish will become larger.

B. If the fish are more active, then they will need more food.

C. If there is more oxygen in the water, then the fish will become larger.

D. If there is more light on the aquarium, then the fish will be more active.

21. Mr. Bixby has an all-electric house and is concerned about his electricity 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 electricity meter.

C. The number of baths taken by family members.

D. A and C.

Appendix 2. Questions for the seesaw activity and the rabbits' activity.

Seesaw virtual lab questions:

Version A: Is it possible to balance the seesaw using a total of 3 objects on the seesaw? If so, then describe exactly how.

Version B: Is it possible to balance the seesaw using a total of 2 objects on the seesaw? If so, then describe exactly how.

Rabbits virtual lab questions:

Version A:

1. Name all the independent variables in this computer model.

2. In this computer model, black rabbits can give birth to a white offspring. How is this possible? Justify.

3. Explain what the characteristics of the two white rabbits in this simulation should be in order to have an equal probability (50%) of giving birth to a rabbit with straight or floppy ears.

Version B:

1. Name all the dependent variables in this computer model.

2. In this computer model, black rabbits can give birth to a white offspring. How is this possible? Justify.

3. Explain what the characteristics of the two black rabbits in this simulation should be in order to have an equal probability (50%) of giving birth to a rabbit with straight or floppy ears.

Appendix 3. Questionnaire on collaborative skills (paper version).

Rate your level of agreement with each statement.

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
My partner was dependent on me for information and advice.					
I was dependent on my partner for information and advice.					
We agreed on what we wanted to achieve.					
When my partner succeeded in their work, this had a positive effect on me.					

1. What was most difficult for you in this collaboration? Why?

2. What do you think is important for collaboration to be successful?