**Integrating ICT in Science Classes: Is it Effective?**

**ABSTRACT**

Many countries integrate information and communication technology (ICT) in science classes as a means to enhance learning, advance digital literacy, and improve student achievement. This study analyzes the effectiveness of integrating ICT into science classes of minority disadvantaged students enrolled in Arabic- speaking public schools in Israel. In these public schools the curriculum is thought in Arabic. Specifically, it examines the effect of integrating ICT on student motivation, sense of self-efficacy, improvement in academic achievement, and collaboration. All participating students were drawn from five classes in two schools, enrolled in the fifth grade in the 2018-2019 school year. The experimental group integrated ICT in learning and the control group adopted traditional learning. The first three measures of effectiveness─ student motivation, sense of self-efficacy, and improvement in achievement ─ were analyzed using quasi-experimental methodology and difference-in-differences (DID) method. Additionally, a qualitative analysis was used to measure student collaboration. Results highlight a greater improvement in achievement and greater collaboration among students in the treatment group as compared to their counterparts in the control group. Changes in student motivation and self-efficacy were not statistically significant. Decision-makers might encourage teachers in training to improve technological capabilities especially in the light of the COVID-19 pandemic which resulted in a significant shift towards online learning.

**Keywords:** ICT, science education, effectiveness, difference-in-differences (DID), public elementary schools, low-SES schools

**Introduction**

In recent decades, there has been a shift from an industrial society to an information society. The driving forces of society and economics have changed from industrial and natural resources to knowledge resources. This process, which has led to an increase in the importance of information and knowledge in all areas of life, is called the “information revolution” (Sorgo, Verckovnik & Kocijancic, 2010). Against this background, there has been a change in both the goals of the education system and ways of achieving these goals. Teaching, in particular, has shifted from the traditional approach, emphasizing knowledge transfer and practice, to innovative teaching which cultivates understanding and critical thinking within an electronic environment in order to provide students with the skills appropriate for the 21st century (Zohar, 2011; Caputo, Buhnova & Walletzky, 2018).

Following this trend, many countries in the world use information and communications technology (ICT) in the classroom, both as a tool to improve student achievement and to promote digital literacy as an end in itself (Livingstone, 2012). In addition, ICT can mediate learning (Bower, 2019) and help develop Social Emotional Learning (SEL) skills that are part of 21st century skill set that strengthens the student's intrapersonal space and focuses on improving student self-management and, in turn, contributes to a learner’s perception of self-efficacy (Benbnishti & Friedman 2020).

The increasing use of ICT in teaching expresses a change in the perception of learning. Learning is no longer perceived as passive acceptance of knowledge from the teacher or the educational system, but rather as a lifelong activity in which learners change their expectations through the seeking of new knowledge. In the course of their lifetimes students will be called upon to seek out and master new knowledge independently. The use of ICT in school is therefore a prerequisite for continuing the lifelong learning process (Fu, 2013).

Proper use of ICT can improve the quality of learning and connect it to real-life situations experienced by learners (Fu, 2013). Integrating ICT in teaching and learning presents several advantages. Firstly, the use of ICT offers additional opportunities for developing critical thinking skills. Secondly, it can improve the quality of learning and teaching and support teaching by providing improved access to learning content (Fu, 2013).

Previous research has found the integration of ICT in science classes to be effective (Kubiatko, 2010; Kubiatko & Vlckova 2010; Ziden et al., 2011) indicating that ICT use improves scientific learning from an early age (Kubiatko, 2010). Additionally, integrating ICT in science classes at the elementary school level has been shown to improve student attitudes toward learning science and to contribute towards improved student achievement (Spiezia, 2010; Ziden et al., 2011). Furthermore, the use of ICT, especially immersive virtual reality in science classrooms, improves student achievement and enhances emotional and social involvement (Liu, Wang, Lei, Wang & Ren, 2020).

There are several metrics that can be used to measure the effectiveness of integrating ICT in learning. These include: student motivation; student collaboration; student self-efficacy; and academic achievement (Fu, 2013). Livingstone (2012) notes that the use of ICT in education in general, and at a young age in particular, contributes to student motivation. Additionally, combining e-learning with face-to-face learning in elementary school expands student opportunities for communication, collaboration, and expression, and increases their willingness to make connections with other students (Anastasiades, Filippousis, Karvunis, Siakas, Tomazinakis, Giza & Mastoraki, 2010). Furthermore, another study that implemented immersive virtual field trips for science learning among elementary students found that motivation of intrinsic value and self-regulation may play a dominant role in students' learning positions in immersive virtual reality for science education environments (Cheng & Tsai, 2020).

Integrating ICT in the classroom is a worldwide phenomenon and Israel is no exception. In 2011, the Israeli Ministry of Education introduced a new educational initiative aimed at integrating ICT into the classroom: "Adapting the Education System to the 21st Century". According to this initiative, the integration of ICT in teaching is a key aspect of adapting the education system to the 21st century, alongside information and communication literacy; critical thinking and problem solving, and communication sharing and teamwork. The goals of the initiative were to develop student motivation, collaboration in learning, and self-efficacy, and to improve student achievement (Ministry of Education, 2011).

The underlying assumption of the Ministry of Education's policy is that ICT is not a necessary condition for the implementation of innovative pedagogy, yet intelligent use of ICT, based on knowledge of its relative advantages and disadvantages, can greatly assist in the implementation of innovative pedagogy (Ministry of Education, 2011).

The Israeli Ministry of Education (2011) initiative is a gradual process with three facets: 1) participating schools (schools will be added to the initiative in a phased manner); 2) scope of implementation (each classroom will be provisioned with a computer and projector screen configuration); 3) grade level (the process will begin at lower grades first before being gradually extended to higher grades).

This study analyzes the effectiveness of integrating ICT in science classes of minority, disadvantaged students, enrolled in Arabic-medium public schools in Israel. Specifically, it examines the effect of integrating ICT on student motivation, sense of self-efficacy, improvement in achievement, and collaboration. The focus on minority, Arabic-speaking, disadvantaged students stems from two principal concerns. Firstly, the scarcity of research in this area (Nachmias, Mioduser, Forkosh, Baruch, 2010) and, secondly, the lack of adequate resources allocated to these students (Abu-Asba, Fresco and Abu-Nasra, 2013; Blass, 2017) as well as elevated rates of underachievement in this category of students (Abu-Asaba, 2007).

In this study we developed a model to evaluate the effectiveness of the Ministry of Education initiative, based on the four dimensions defined by the Ministry of Education ICT project: motivation, self-efficacy, academic achievement and student collaboration.

**Integrating ICT in class**

As in the other professions, the teaching of the natural sciences is increasing, and attempts are being made to assimilate the use of digital technology within teaching, like personal computers, mobile devices, and the internet for synchronous learning, online forum management, and more. Computer-generated technology emphasizes branching and multidimensional thinking and the illustration of complex phenomena: all features necessary in science teaching (Klein, 2011). However, a review of information on the integration of laptops in science teaching shows that implementation is still in its infancy, as is the scope of the studies that accompany it (Paz & Salant, 2010).

ICT integration includes the use of computers, the internet, and other media such as radio and television. In many Western countries, ICT is widely used in education (Fu, 2013; Livingstone, 2012; Sánchez & Alemán 2011), and its integration in education continues to expand (Fu, 2013). The increasing use of ICT in teaching reflects a change in the perception of learning, which is no longer seen as a passive reception of knowledge from the teacher, but as an ongoing, lifelong activity in which learners seek knowledge over time from new sources (Fu, 2013).

Integrating ICT into learning processes has several benefits (see Fu, 2013; Sánchez & Alemán, 2011; Chai et al., 2010). However, the mere use of ICT in teaching does not guarantee all these advantages; it is likely to be more beneficial when integrated with relevant pedagogy. Furthermore, the integration of ICT in class may also have a negative impact on learning (Martinovic & Zhang, 2012). Another scenario concerns the personal aspects of teaching and learning: if the use of ICT replaces the teacher-student relationship, the student might perceive a lack of feedback from the teacher, which may not only make it more difficult to understand the material but also damage the student’s self-confidence (Fu, 2013).

***Integrating ICT in science class***

Previous research has found integrating ICT in science classes to be effective (Kubiatko, 2010; Kubiatko & Vlckova 2010; Ziden et al., 2011; Zucker et al., 2008). Specifically, the use of ICT has increased high school students’ interest in science. Similar findings were reported for elementary schools. In a study comparing an experimental group that studied science using ICT with a control group that studied science using traditional means only, ICT use not only improved student attitudes toward the material taught and science in general, but also improved achievement (Ziden et al., 2011; Zucker et al., 2008).

**Measuring the effectiveness of integrating ICT in class**

It has been noted in the literature that ICT integration has the potential to be effective in terms of (1) student motivation, (2) student collaboration, (3) student self-efficacy, and (4) academic achievement (Fu, 2013). Using ICT in education in general, and at a young age in particular, contributes to increased student motivation (Livingstone, 2012). Additionally, integrating online learning with face-to-face learning widens student opportunities for collaboration, and increases their willingness to connect with other students (Anastasiades et al., 2010). Finally, the use of ICT contributes to improving academic achievement, especially in science (Ziden et al., 2011).

**The Israeli context**

In Israel, two local initiatives integrate ICT in science classes: the “Laptop for Every Student Project” and the “Classroom Computer Student and Teacher Project.” As part of these initiatives, science teaching is conducted through animated videos. For example, videos are used to teach “Earth and the Universe” in elementary school, and “Materials and their Properties” in middle school (Klein, 2011).

While research on the effectiveness of ICT integration in science classes in Israel is scarce, studies on integrating ICT in classes in general (without focusing on science) have been conducted more frequently (Brandes & Strauss, 2013). In a study examining high school teachers’ and students’ attitudes toward a program teaching biology using computers in Israel, both teachers and students identified with the program’s goals for integrating ICT into life science teaching (Shemesh et al., 2008).

Although many initiatives at both the national and local level have been implemented to promote ICT integration in the classroom, the incorporation of new technologies into the education system has not kept pace with technological developments. Furthermore, the current gap between the possibilities afforded by ICT and its actual uses is significant, and the state of the infrastructure and students’ levels of access to computers and the internet are still very limited (Vorgan, 2010).

Despite these challenges, research based on classroom observations suggests that introducing laptops into classrooms may contribute to the adoption of innovative pedagogies, because the practice has the potential to promote the development of skills, such as collaborative learning, crucial to the 21st century (Manny-Ican et al., 2013). In addition, c In a more recent study, Getz and Goldberg (2016) found that since Vorgan’s (2010) study, the situation in Israel has improved with regard to the integration of instructional ICT, partly because of the implementation of the 21st-Century Education Adjustment Program and the activities of the “Thought Center,” which was founded to support teachers in using computers in Israel (Getz & Goldberg, 2016). However, despite this improvement, Nir and his colleagues (2016) report that the changes have put much pressure on teachers and administrators to fulfill technological requirements. Specifically, owing to the large effort invested in dealing with technology, teachers report lack of time for significant in-person teaching.

**This study examines the following questions:**

1. Does student motivation in the ICT program improve as compared to their counterparts in the traditional program?
2. Does student self-efficacy in the ICT program improve as compared to their counterparts in the traditional program?
3. Does student achievement in the ICT program improve as compared to their counterparts in the traditional program?
4. Is there greater collaboration between students in the ICT program as compared to their counterparts in the traditional program?

**Methodology**

**Procedure**

Participating students were drawn from five classes in two schools, enrolled in the fifth grade in Arabic-medium public schools in Israel in the 2018-2019 school year.

Both schools are located in the same geographic area and are classified as Arabic-medium public schools. The school from which we recruited the control group is the only elementary school in the area that, at the time of the study, had not yet participated in the ICT national program; it was selected because it closely resembled the demographics of the school integrating ICT into science classes (e.g., geographical area, socioeconomic status, and the heterogeneous level of achievement). The classes constituting the sample were heterogeneous and integrated students with special educational needs and learning disabilities.

The experimental group had ICT integrated into their classes and the control group were taught using traditional methods. The study lasted one school year. Data collection was conducted at two points: before and after the intervention. In September 2018, the first month of the school year, the first data measurement was performed using the same research tools (detailed below) for both groups. Later, in early October, the intervention in the experimental group began, and lasted until the end of the school year. The lessons that were part of the intervention program were delivered by the science teachers twice a week throughout the school year. At the same time, the control group, using the same sequence and timeline, studied the same material using traditional methods. In early June, towards the end of the school year, data was collected from the two groups for the second time, using the same research tools as in the first measurement.

Pre- and post-measurements were carried out in the intervention group (students studying in a program that integrated ICT in learning) and a control group (students in the traditional program). However, the experimental conditions could not randomly assign students into classes. Both groups were assessed at two points in time, prior to the implementation of the ICT program, and at the end of the academic year.

**Intervention Program (National ICT Project)**

The Educational Technology Center (MindCET), which focuses on combining technology and pedagogy in collaboration with the Ministry of Education, developed a program in science that integrates a computer-based curriculum for teaching and learning science in the fifth grade. A subcommittee formed by the schools participating in the study chose their specific ICT-based lessons from within a larger resource database of lessons and activities created by MindCET. Approximately 35 science lessons were delivered throughout the school year; one of the twice-weekly sessions always took place in a computer lab with digital only interface, and the second weekly science lesson was held in an ordinary classroom using laptop computers.

In comparison, the fifth graders in the control group attended a school in which the national curriculum was also taught but using traditional teaching methods. For example, most of the lessons were delivered using textbooks and regular lab activities prepared by the teacher. Occasionally, the teacher used a computer for frontal teaching purposes.

In the experimental group, the science studies incorporated a variety of innovative technologies including digital books, web applications, and e-learning platforms. A sample lesson plan from the experimental group is presented in Appendix A.

Teachers in the experimental (ICT group) received training before the program began from an ICT instructor from MindCET. This was accompanied by ongoing assistance and monitoring of the science center at the school. The subjects in the ICT program were the same as those from the traditional science curriculum in the control schools. The students received a detailed explanation of the use of a platform that included MindCet’s ICT program in science.

**Instruments**

In order to examine the research hypotheses on the variables of (1) motivation, (2) self-efficacy, and (3) achievement, the following instruments were used:

*Student motivation questionnaire*

The Personal Achievement Goal Orientation (PAGO) scale by Midgley et al. (1998) was used to measure student motivation. The questionnaire is comprised of 24 items rated on a 5-point Likert scale ranging from “5= strongly disagree” to “1= strongly agree.” The questions included in the questionnaire are designed to elicit information about the specific drivers that motivate students to put effort into their school work and to perform well. The questions can be broadly divided as testing the importance of three motivators which Midgley et al. (1998) refer to as “task orientation”, “performance-approach orientation”, and “performance-avoid orientation”. Broadly speaking these three motivators can be understood, respectively, as: satisfaction gained from gaining new knowledge and skills; satisfaction gained from outperforming peers; avoiding the embarrassment of performing more poorly than others. Examples of task-oriented motivators include: “I like school work that I’ll learn from, even if I make a lot of mistakes” and “an important reason I do my school work is because I enjoy it.” Questions which test the performance-approach orientation include: “I want to do better than other students in my classes” and “I’d like to show my teachers that I’m smarter than the other students in my classes.” Finally, the “Performance-avoid orientation is measured by questions like: “It’s very important to me that I don’t look stupid in my classes” and “the reason I do my work is so others won’t think I’m dumb.” The internal consistency score of the questionnaire as determined in previous studies ranged from 0.71 to 0.80 (Midgley et al., 1998), and was 0.66 in our study. The score was calculated by averaging questions answered by the respondent. The questionnaire was translated into Arabic by teachers with professional translation experience and reviewed by two other teachers to verify accuracy. In addition, confirmatory factor analysis (CFA) with adjustment was carried out, yielding a comparative fit index (CFI) of 0.968.

***Self-efficacy questionnaire***

Chen & Gully (1997) designed a questionnaire to measure perceptions of self-efficacy which is defined as a student’s belief in their capacity to execute behaviors necessary for the attainment of goals. The questionnaire is comprised of 14 items rated on a 5-point Likert scale ranging from “1= Not at all describing me” to “5= Describing me to a great extent.” The questions are designed to measure a student’s confidence in their own ability and their own capacity to acquire new knowledge and skills. Some examples of the questions included in the measurement instrument are: “I will be able to achieve most of the goals that I have set for myself”; “I believe I can succeed at most any endeavor to which I set my mind”; “I will be able to successfully overcome many challenges”. The remaining questions are designed along a similar vein and the results of the questionnaire, when taken as a whole, are a very good predictor of a student’s self-efficacy.

The questionnaire was translated into Arabic by teachers versed in translation and tested by two teachers to verify accuracy. Our reliability score was 0.84, again averaging all questions to which the respondent replied. In addition, CFA with adjustment was again performed, yielding a CFI of 0.906.

***Science achievement test***

A structured achievement test was developed for the purposes of this study by a science-based steering team. It included knowledge and comprehension questions on science subjects taught in school and was validated by a content table featuring all test items, including a weight and level for each item. Examples of the types of questions posed include: “Write two examples of adaptation in the body structure of an animal to the environment”; “For whom is breathing an essential need? Circle the most correct answer”; “The common properties of liquids and gases are:”; “Animals breathing with gills belong to class:” etc.

The test was translated and administered to the students in Arabic. When checking for reliability in terms of internal traceability, we obtained a 0.86 correlation between the two sections of the test. To calculate the final reliability value, a correction according to the Spearman-Brown formula (Gulliksen, 1987) was performed, yielding a 0.92 correlation.

***Structured* *observation to assess student collaboration***

We used structured observations to evaluate student collaboration during the students’ preparation of a final product in group work. The observations were conducted using a reporting template created by Wadawi et al. (2013). Collaboration was evaluated by three observers, each of whom observed both the experimental and control groups on three different occasions. In each instance, the researcher and two additional observers from the science team noted their observations with the reporting template, to ensure the reliability of the data. At the end of each observation, the researcher and the two other observers cross-commented on each criterion included in the structured observation. At the end of the observation period, all nine observations were pooled together for analysis.

***Qualitative data analysis***

To examine the structured observations of student collaboration and classify concepts based on an ongoing comparison and search for similarity, variation, and complementarity, we analyzed the pooled observations using the phenomenography approach (Marton, 1986). The approach is based on the collection of descriptions, sentences, statements, ideas, thoughts, and experiences during fieldwork. Analysis began with the identification of common features and patterns in the data collected, on the basis of which, preliminary conceptual categories were formed. After “refining” the categories and determining their hierarchy, criteria for including a data point in each category were developed. Descriptions of the three observations by all observers were mined for similarities.

***Quantitative data analysis***

Difference in Differences (DID) is a statistical research technique that can be used in quantitative research when not all variables are predictable, measurable or avoidable. It is effective at imitating experimental research design in which variables can and must be accounted for. This model has been adopted widely, particularly in economic studies; a pioneering analysis of this type was employed by Card and Krueger (1994). It is thus useful for mitigating the impact of unknown variables on the outcomes of a study. The DID method allowed us to measure the net impact of integrating ICT into science classes on student performance while controlling for student background characteristics.

DID is typically used to calculate the effect of a treatment by measuring the change over time in the outcome variable between two groups: one which receives the treatment (the treatment group) and one which does not (the control group) (Angrist and Pischke ,2008; Dadon-Golan et al, 2020). In our case the treatment group refers to the students exposed to ICT and the control group is the students who were taught using traditional approaches. As discussed above, measurements were taken at the beginning and the end of the school year.

The DID estimate can be calculated in two main ways. The first, in the form of an algebraic- graphic table, as discussed in the following hypothetical example and the second, by employing regression analysis. This serves as a convenient way to build the model and to ascertain the influence of the interaction effect of the difference in differences.

The DID estimate can be calculated in two main ways. The first, in the form of an algebraic- graphic table, as discussed in the foregoing hypothetical example and the second, by employing regression analysis. This serves as a convenient way to assemble the model and to ascertain the influence of the interaction effect of the difference in differences.

To measure the impact of the integration of ICT in science classes, we compared the average change in the experimental group with the average change in the control group at two corresponding time points (before and after the intervention), using multiple linear regression analyses, where the dependent variable was the evaluative measure, and the explanatory variables were the pre or post intervention measurements (in our case, ICT-integrated vs. traditional learning), and the interaction between intervention and time. A statistically significant interaction indicates that the impact of integrating ICT in science classes is significant.

To test the hypothesis, which proposes an increase in achievement among students in the ICT program compared to their peers in the traditional program, the following DID equation was formulated (**Eq. 1**):

$$G(i)=a+β\_{1}C+β\_{2}T+β\_{3}I+e$$

where *G* is the grade of student *i*; $a$ is the cutter; *β* is the regression coefficient; *C* is the group (treatment/control); *T* is the time (before/after); *I* is the interaction (*C × T*); and *e* is the error term.

To test the hypothesis, expecting a greater increase in motivation among fifth-graders at Arabic-medium public schools with ICT integration in science classes as compared to that among their peers studying in the traditional manner, the following DID equation was formulated (**Eq. 2**):

$$M(i)=a+β\_{1}C+β\_{2}T+β\_{3}I+e$$

where *M* is motivation of student *i*; $a$ is the cutter; *β* is the regression coefficient; *C* is the group (treatment/control); *T* is the time (before/after); *I* is the interaction (*C × T*); and *e* is the error term.

To test the hypothesis, expecting a greater increase in self-efficacy among students on the ICT program compared to their peers attending the traditional program, the following DID equation was formulated (**Eq. 3**):

$$SE(i)=a+β\_{1}C+β\_{2}T+β\_{3}I+e$$

where *SE* is the self-efficacy of student *i*; $a$ is the cutter; *β* is the regression coefficient; *C* is the group (treatment/control); *T* is the time (before/after); *I* is the interaction (*C × T*); and *e* is the error term.

**Results**

The "treatment" was applied to one group (i.e. ICT-integrated science classes) but not to the other (traditional learning without ICT integration).We estimated the difference-in-differences using the two DID approaches described above: the algebraic and regression methods. Regarding student achievement, the first difference was that between student achievement at the end of the school year (after) and student achievement at the beginning of the school year (before) in the traditional method group. The second difference was produced by comparing student achievement at the end of the school year (after) and student achievement at the beginning of the school year (before) in the ICT group. Finally, the difference between the differences was calculated as the difference between the second difference and the first difference.

Table 1 presents the results of the DID calculation according to Equation 1(see above). The table presents the average score of student achievement with a higher score representing higher levels of achievement.

Table 1

*Means and Standard Deviations of Student Achievement in the Experimental and Control Group*

|  |  |  |
| --- | --- | --- |
| *Measurement* |  | *Group*  |
|  |  | *Achievement* |  |
| *After* | *Before* |  |  |
| 70.97 | 61.16 | Mean | Experimental group (N = 88) |
| 15.4 | 16.64 | SD |
| 71.42 | 69.74 | Mean | Control group (N = 57) |
| 15.47 | 15.69 | SD |

As Table 1 shows, the level of achievement increased from the beginning of the school year to the end of the school year in both the group that studied in the traditional program (from 69.74 to 71.42) and the group that studied the ICT program (from 61.16 to 70.97).

The difference between the average student achievement in the traditional program as compared to the ICT program was 8.58 at the beginning of the school year and 0.45 at the end of the school year.

Moreover, the difference between the average grades of students at the beginning of the school year and the end of the school year was 1.68 for students in the traditional program and 9.81 for students studying in the ICT program. The results clearly indicate that students in the ICT program achieved considerably higher grades by the end of the school year (9.81) as compared to students in the traditional program(1.68). The results are a significant difference of 8.13. They are shown graphically in Figure 1 below.



*Figure 1*. Means and Standard Deviations of Student Grades in the Experimental and Control group.

In conclusion, the mean score of student achievement in the experimental group increased after the intervention (9.81); as he did in the control group (1.68). Accordingly, the net effect of the teaching method was an increase from 1.68 to 9.81: a significant difference. In the light of this considerable difference in average grades between the ICT and traditional groups following the intervention, it is clear that ICT teaching methods had an important positive impact on student achievement.

The above results are confirmed in Table 2 below which reports the regression findings according to the DID method. These were calculated according to Equation 1, with student achievement as a dependent variable. Similar to the findings of the algebraic method, the results of the regression analysis indicate a statistically significant effect of ICT teaching methods on student achievement.

*Table 2 Testing Differences in Achievement*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *α significant* | *SE* | *B* | *β* | *Variable* |
| 0.000 | 2.100 | - | 71.421 | Fixed |
| 0.571 | 2.970 | 0.051 | 1.684 | Time |
| 0.002 | 2.696 | -0.256 | -8.578 | Program (ICT) |
| 0.034 | 3.812 | 0.228 | 8.123 | Time \* ICT |
|  | R2=0.074 |  |  |

The table indicates that the coefficient for the ICT learning method is significant at the 0.05 level. More importantly, here the regression analysis did indeed show the interaction effect representing the significance of the effect using the difference (Table 2). This indicates a significant difference in the change in achievement between the programs (Fig.1). The increase in achievement between measurements was higher for students in the experimental ICT program than for those in the traditional program. Overall, our results indicate a positive effect of the teaching method on student achievement.

Regarding student motivation, measurements were taken at the beginning of the school year (before) and at the end of the school year (after) in the group that studied using traditional methods resulting in difference 1. The motivation levels of the treatment group, the ICT group, were also measured before and after yielding difference 2. The DID is the difference in turn between differences 1and 2.

Table 3 presents the research findings that arise in the DID calculation described in Equation 2. The table shows the average motivation score on a Likert scale ranging from 1 (strongly agree) to 5 (strongly disagree), with a lower score representing higher levels of motivation.

Means and Standard Deviations of Student Achievement in the Experimental and Control Group

Table 3

*Means and Standard Deviations of Student Motivation in the Experimental and Control Group*

|  |  |  |
| --- | --- | --- |
| *Measurement* |  | *Group* |
| *Motivation* |
| *After* | *Before* |  |  |
| 2.26 | 2.28 | Mean | Experimental group (N = 88) |
| 0.52 | 0.48 | SD |
| 2.24 | 2.23 | Mean | Control group (N = 57) |
| 0.43 | 0.34 | SD |

As Table 3 shows, the level of motivation shifted in both groups over the course of the school year. In the group that studied in the traditional program motivation decreased slightly (from 2.23 to 2.24) while increasing slightly in the group which studied the ICT program (from 2.28 to 2.26). The difference between average motivation score in the traditional program and average motivation score in the ICT program was 0.05 at the beginning of the school year and 0.02 at the end of the school year. The difference between the average motivation level of the students at the beginning of the school year and the difference between the average motivation levels of their motivation at the end of the school year was 0.01 for students in the traditional program and -0.02 for students studying in the ICT program. The ICT program students experienced a small increase in the level of motivation by the end of the school year (-0.02) while the traditional program students suffered a small decrease in their level of motivation by the end of the school year (0.01), resulting in a very small difference of 0.03 between the treatment and control groups. Given this small difference in the positive outcome our interpretation is that the ICT learning method has very little, if any, effect on motivation.

 These results are illustrated in Figure 2.



*Figure 2* Means and Standard Deviations of Student Motivation in the Experimental and Control Group.

The above results are confirmed in Table 4, which reports the regression findings following to the DID method, calculated according to Equation 2, with the level of motivation as the dependent variable. Similar to the findings from the algebraic method, the results of the regression analysis indicate that the treatment had no statistically significant effect on student motivation.

*Table 4 Differences in Motivation*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *α significant* | *SE* | *B* | *β* | *Variable* |
| *Motivation* |
| 0.000 | 0.061 | - | 2.302 | Fixed |
| 0.767 | 0.086 | - 0.028 | -0.025 | Time |
| 0.657 | 0.078 | -0.037 | -0.033 | Treatment (ICT) |
| 0.819 | 0.110 | 0.026 | 0.024 | Time \* ICT |
|  R2=0.001 |  |  |

The table indicates that the coefficient for the ICT learning method is not significant at the 0.05 level. More importantly, the effect of the interaction, which represents the extent of the effect using the difference indifferences model, is also not significant (Table 4). Specifically, students at the end of the school year who were in the experimental group show a slightly higher level of motivation than the control group. Overall, our results indicate a positive but negligible effect of the ICT learning method on the level of motivation among students.

Identically to the measurements for achievement discussed above, the measurements for self-efficacy were taken at the beginning of the school year (before) and at the end of the school year (after) in the group that studied using traditional methods resulting in difference 1. The motivation levels of the treatment group, the ICT group, were also measured before and after yielding difference 2. The DID is the difference in turn between differences 1and 2.

Table 5 presents the findings of the study that arise from the calculation of the DID as described in Equation 3. The table shows the average score of the abilities, related to their level of motivation, on a Likert scale ranging from 1 (Not at all describing me) to 5 (Describing me to a great extent). With a higher score representing higher levels of ability.

Table 5

*Means and Standard Deviations of Student Self-Efficacy in the Experimental and Control Group*

|  |  |  |
| --- | --- | --- |
| *Measurement* |  | *Group* |
| *Self*-*Efficacy* |
|  *Before After* |
| 1.69 | 1.7 | Mean | Experimental group (N = 88) |
| 0.7 | 0.7 | SD |  |
| 1.71 | 1.67 | Mean | Control group (N = 57) |
| 0.43 | 0.48 | SD |  |

As Table 5 shows, there was a change in the level of self-efficacy in both groups over the course of the school year. The students that studied in the traditional program experienced a slight increase in self-efficacy (1.67 to 1.71). The ICT group suffered a slight decrease (1.7 to 1.69).

The difference in the average score of self-efficacy in the traditional program and the average score of self-efficacy in the ICT program was 0.03 at the beginning of the school year and -0.02 at the end of the school year. Again, the difference in the mean self-efficacy level of students at the beginning of the school year and the average difference in their self-efficacy level at the end of the school year was 0.04 for students in the traditional program and -0.01 for students studying in the ICT program. More precisely, those who studied in the ICT program suffered a small decrease in their level of ability at the end of the school year (-0.01). Those who studied in the traditional program experienced a small increase in the level of ability at the end of the school year (0.04), resulting in a very small difference of 0.05. These results are shown graphically in Figure 3.



*Figure 3*. Means and Standard Deviations of Students’ Self-efficacy in the Experimental and Control Group.

In conclusion, students who studied science in the ICT-integrated program had less self-efficacy at the end of the school year after the intervention (-0.01). Had they been in the traditional program in the control group, the increase in self-efficacy would have been small (0.04). Accordingly, the net effect of the teaching method is a decrease from 0.01 to 0.04: a difference of 0.05. Given this small difference in the positive outcome, our interpretation is that the ICT learning method has very little, if any, effect on self-efficacy.

The above results are confirmed in Table 6, which reports the regression findings according to the DID method, calculated according to Equation 3, with the level of self-efficacy as a dependent variable, similar to the findings from the algebraic method, the regression analysis results indicate no statistically significant effect on self-efficacy among the students.

*Table 6 Differences in Self-Efficacy*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *α significant* | *SE* | *B* | *Β* | *Variable* |
| *Self-Efficacy* |
| 0.000 | 0.082 | - | 1.776 | Fixed |
| 0.248 | 0.115 | - 0.109 | -0.124 | Time |
| 0.058 | 0.105 | - 0.159 | -0.184 | Program (ICT) |
| 0.296 | 0.148 | 0.117 | 0.143 | Time \* ICT |
|  R2 = 0.014 |  |  |

The table indicates that the coefficient for the ICT learning method is not significant at the 0.05 level. More importantly, the effect of the interaction representing the extent of the effect using the difference-in-difference model is also insignificant (Table 6). Specifically, students at the end of the school year who were in the experimental group exhibit a lower level of ability than the control group. Overall, our results indicate a positive, but very small, effect of the ICT learning method on the level of competence among students.

A final important metric for the efficacy of the ICT program vis-à-vis the traditional program concerns comparing the level of collaboration attained in the two groups for which structured observation was utilised. Table 7 below shows that the level of collaboration among students enrolled in the ICT-integrated program was greater with respect to the following aspects: the level of interest in learning from peers, student trust, encouragement and support among group members, student willingness to study in a group, quality of communication between group members, and student self-confidence in group learning. An analysis of the observations revealed that a high degree of collaboration was consistently seen across all three observations.

In contrast, observations of the traditional learning program were mixed, suggesting that collaboration between students in the control group was partial and inconsistent. Regarding interest in learning from peers, some observations revealed a high level of interest, whereas others noted interest in learning from peers only in some of the task phases. Concerning student trust, during most observations a trusting atmosphere among students was perceived, but in one observation trust among the students was seen in only some of the groups. In terms of encouragement and support among group members, some of the observations did not see mutual encouragement by the students, while others saw encouragement of only the high-achieving students. Regarding student willingness to study in a group, the observations were split between instances in which most of the students expressed a willingness to study in groups, and others in which only some of the students expressed enthusiasm. In communication between group members, two observations reported good communication between most students during the group tasks, whereas one observation noted good communication in only some of the groups. With regard to students’ self-confidence during group work, only some of the students demonstrated self-confidence, especially the high-achieving ones who received encouragement.

Table 7 Differences in Collaboration among Students during Presentations

|  |  |  |
| --- | --- | --- |
| *Degree of collaboration - control group* | *Degree of collaboration - experimental group* | *Checklist Criteria*  |
| 3 out of 5 groups presented very good organization - elements of organization.Some groups presented | 5 out of 5 groups presented very good organization - elements of organization.All groups presented | **General class organization**  |
| Some of the more organized students participated in the presentationSome of the less organized students participated in the presentationGeneral interest was shown in some of the groups through questions and general contribution | Most of the more organized students participated in the presentationMost of the less organized students participated in the presentationGeneral interest was well shown in all groups through questions and general contribution | **Degree of interest in learning from peers** |
| Some of the more organized and prepared students are asked questions.The less organized and prepared students were not asked questions Some students evaded the situation and did not ask questions  | Most of the more organized and prepared students were asked questions.The less organized and prepared students were also asked knowledge based questions The majority asked questions | **Trust among students** |
| Students in some of the groups show interest in helping one another | Students in all the groups show interest in helping one another | **Encouragement and support among team members** |
| Some of the students showed willingness | Most of the students showed willingness | **Students' willingness to study in a group** |
| Among the groups that presented their works in the different activities, some were organized and some presented in coordination with the group membersSome of the students in the group staff communicated wellProlonged preparation did not help them to communicate well | The groups that presented their works in the different activities were all organized and each presented in coordination with the group membersMost of the students in the group staff communicated wellProlonged preparation caused them to communicate well | **Communication capabilities among team members** |
| Only the well-prepared students showed confidenceTrust and encouragement were not always present among all the studentsOnly some students demonstrated confidence and self-assuredness when learning from their peers | All the students were well prepared and showed confidenceTrust and encouragement were present among the studentsInterest in learning from their peers encouraged more confidence and self-assuredness | **Self-confidence** |
| Partial class participation expressed a moderate assessment | Class participation expressed a positive formative assessment | **General Assessment of Learning Outcomes** |

**Discussion**

The purpose of this study was to examine the effectiveness of integrating ICT in science classes in Israel. The effectiveness measures were selected to align with the original goals of the ICT national program (Brandes & Strauss, 2013). our findings are consistent with previous research showing that ICT programs improve student achievement (Kubiatko, 2010; Ziden et al., 2011; Zucker et al., 2008) and that ICT integration is effective at improving achievement in science and scientific literacy (Spiezia, 2010).

Our findings on student collaboration concur with previous research that showed ICT-integrated learning combined with face-to-face learning expands student opportunities for communication and collaboration, supports their ability to express themselves, and increases their willingness to connect with other students (Anastasiades et al., 2010). The ICT program also improved student collaborative learning in terms of their interest in learning from peers, student trust, encouragement and support among group members, students’ willingness to study in groups, communication skills among group members, and students’ self-confidence in group learning. Collaborative learning contributes to improved academic achievement, and ICT supports learning through discussion (Kubiatko & Vlckova, 2010). Our observations indicate that ICT use did indeed contribute to learning through discussion, which may be one of the factors that significantly improved students’ achievement.

In contrast, the results of the study show that, contrary to expectations, there were no significant differences between the groups regarding improvement in motivation. This finding is inconsistent with the findings of Livingstone (2012), who proposes that the use of ICT in education in general, and at an early age in particular, contributes to increasing student motivation and with those of Kubiatko (2010), who showed that the use of ICT in science instruction increased students’ interest in the material being studied.

There are two possible explanations for this discrepancy. The first explanation is based on the distinction between the ICT program’s design and its implementation. According to Vorgan (2010), the gap between the possibilities afforded by ICT and its actual use can lead to some of the program goals not being realized (Brandes & Strauss, 2013). The actual implementation of the ICT program may not bring out the program’s full potential, and thus not increase motivation. According to this explanation, training teachers to deliver a more successful implementation of the program may improve student motivation.

A second possible explanation concerns the premises of the ICT program itself. Due to the technological requirements, the implementation of such a program creates great pressure on teachers and administrators. Specifically, due to the effort invested in managing the technology, teachers do not have time for significant in-person teaching (Nir et al., 2016). According to this explanation, the teachers might have been so occupied with implementing the technology that they had less time for in-person interactions with the students. Personal contact in teaching is an important factor affecting student interest and involvement in class. As a result of the reduction in contact, student motivation may have decreased. Alternatively, this decrease could have been balanced with the increase in motivation that other studies (Livingstone, 2012; Kubiatko, 2010) associate with the use of ICT, so that, in effect, no group difference in the change in student motivation was observed.

Our findings on self-efficacy do not align with previous research. While the literature finds a positive relationship between the use of ICT and self-efficacy (Celik & Yesilyurt, 2013), our study found no significant differences. One explanation may, again, be the gap between the potential of ICT and its actual use (Vorgan, 2010), preventing the realization of some of the program’s goals (Brandes & Strauss, 2013), including the enhancement of students’ sense of self-efficacy. The second explanation might be inherent in the ICT program. According to Fu (2013), when ICT replaces the teacher-student relationship, the student may receive insufficient teacher feedback; this deficit may make it difficult for the student to understand the material and also impede the development of self-confidence. According to this explanation, when students do not receive the teacher feedback they need in the learning process, even though they may assimilate the material and improve their achievement, they may still not feel confident and therefore not improve their sense of self-efficacy.

In line with these explanations, it is not surprising that the present study, like previous research, finds that the ICT program improves student achievement in the sciences. In addition, apart from enhancing ability to understand abstract subjects, improving scientific literacy, and supporting high-order thinking ability, we found that ICT might also improve students’ achievement via collaboration.

**Conclusions**

The study examined the effectiveness of integrating a comprehensive digital learning program in fifth-grade science studies in Arabic-medium schools in Israel. Our findings show that the ICT program is very effective in terms of improving achievement among students and very effective in terms of creating collaboration between students. ICT also makes it possible to illustrate abstract topics and develop higher-order thinking. The ICT program improves the ability and willingness of students to work in groups and therefore increases collaboration between students. It is possible that collaborative learning, in itself, also contributes to improved achievement.

In contrast, our findings show that the program was ineffective in terms of increasing student motivation and self-efficacy, maybe owing, in part, to the underutilization of ICT in the classroom, and to lack of feedback from the teacher with the result that self-efficacy does not increase despite increased achievement.

**Limitations and further research**

This study has several limitations. First, the assignment of students into control and treatment groups was not randomized; thus, selection bias might blur our findings. We used DID methodology as a mean to avoid this bias as much as possible. Second, the school sample was not random, which might affect the effectiveness of ICT integration observed. Both factors limit the generalizability of these results.

Third, the study examined student achievement in general, without looking at specific aspects of knowledge and comprehension; future research should test the effect of the ICT program on more specific aspects of students’ skills.

Fourth, since the study compared the ICT program only to a traditional program, it could not evaluate its effectiveness compared to other types of non-traditional programs.

Fifth, while computer literacy was not measured, it may also have affected the research findings; future research should examine and take into account computer literacy. In addition, the two groups were taught by different teachers; for future research a design deploying the same teachers is recommended, so that only the teaching method is varying.

Future studies in other countries that have minority populations suffering from educational resource constraints could benefit from the findings of this study.

**References**

Abu-Asaba, H. (2007). *Arab education in Israel: Dilemmas of a national minority*. Jerusalem: The Floorsheimer Institute for Policy Studies. (In Hebrew)

Abu-Asba, H, Fresco, B. & Abu Nasra, M. (2013).) *Dropout of students in Arab-Bedouin and Druze education*; Final report. the Ministry of Education, Culture and Sport. (In Hebrew)

Anastasiades, P. S., Filippousis, G., Karvunis, L., Siakas, S., Tomazinakis, A., Giza, P., & Mastoraki, H. (2010). Interactive videoconferencing for collaborative learning at a distance in the school of 21st century: A case study in elementary schools in Greece. *Computers & Education, 54(2),* 321–339.

Angrist, J. D., & Pischke, J. S. (2008). *Mostly harmless econometrics: An empiricist's companion*. Princeton, NJ: Princeton University Press.

Benbnishti, R. & Friedman, T. (2020). Cultivation of Social Emotional Learning (SEL). *Center for Knowledge and Research in Education*. (In Hebrew)

Blass, N. (2017). *The academic achievements of Arab students*. Jerusalem: Taub Center for the Study of Social Policy in Israel.‏ (In Hebrew)

Bower, M. (2019). Technology ‐mediated learning theory. *British Journal Education Tech- nology*, 50, 1035–1048. 10.1111/bjet.12771.

Brandes, A., & Strauss, A. (2013). *Education for a society of culture and opinion—changes in the 21st century and their implications: Recommendations for adapting the education system in Israel to the 21st century*. Jerusalem: Israeli National Academy of Sciences. (In Hebrew)

Caputo, F., Buhnova, B., & Walletzký, L. (2018a). Investigating the role of smartness for sustainability: insights from the Smart Grid domain. *Sustainability Science*, 1-11.

Card, D., & Krueger, A. B. (1994). Minimum wages and employment: A case study of the fast food industry in New Jersey and Pennsylvania. *The American Economic Review, 84(4),* 772–793.

Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2010). Facilitating preservice-teachers' development of Technological, Pedagogical, and Content Knowledge (TPACK). *Educational Technology & Society, 13*(4), 63–73.‏

Chen, G., & Gully, S. M. (1997, August). *Specific self-efficacy, general self-efficacy, and self-esteem: Are they distinguishable constructs*? Paper presented at the57th annual meeting of the Academy of Management, Boston.

Chen, G., Gully, S. M., & Eden, D. (2001). Validation of a new general self-efficacy scale. *Organizational Research Methods, 4*(1)*,* 62–83.

Cheng, K.-H., & Tsai, C.-C. (2020). Students’ motivational beliefs and strategies, perceived immersion, and

attitudes towards science learning with immersive virtual reality: A partial least squares analysis. British

Journal of Educational Technology.

Cheng, K.-H., & Tsai, C.-C. (2020). Students’ motivational beliefs and strategies, perceived immersion, and

attitudes towards science learning with immersive virtual reality: A partial least squares analysis. British

Journal of Educational Technology.

Cheng, K.-H., & Tsai, C.-C. (2020). Students’ motivational beliefs and strategies, perceived immersion, and

attitudes towards science learning with immersive virtual reality: A partial least squares analysis. British

Journal of Educational Technology.

Cheng, K.-H., & Tsai, C.-C. (2020). Students’ motivational beliefs and strategies, perceived immersion, and

attitudes towards science learning with immersive virtual reality: A partial least squares analysis. British

Journal of Educational Technology.

Cheng, K.-H., & Tsai, C.-C. (2020). Students’ motivational beliefs and strategies, perceived immersion, and attitudes towards science learning with immersive virtual reality: A partial least squares analysis. *British Journal of Educational Technology.*

Dadon-Golan, Z., Ziderman, A., & Ben David-Hadar, I. (2020). Impact of university attendance on students’ political tolerance and open-mindedness: The atypical case of Israel. *Journal of Applied Research in Higher Education.*

Fu, J. S. (2013). ICT in education: A critical literature review and its implications. *International* *Journal of Education and Development Using Information and Communication Technology, 9*(1)*,* 112–125.‏

Getz, D., & Goldberg, I. (2016). *Best practices and lessons learned in ICT sector innovatio*n:‏ *A case study of Israel*. Washington, DC: World Bank Group. Retrieved from http://documents.worldbank.org/curated/en/657111468185331183/Best-practices-and-lessons-learned-in-ICT-sector-innovation-a-case-study-of-Israel.

Gulliksen, H. (1987). Theory of mental tests. Hillsdale, NJ: Erlbaum.

Klein, S. (2011). *Content and skills combinations in teaching and learning of the natural sciences according to the curriculum in Israel*. Jerusalem: Israeli National Academy of Sciences. (In Hebrew)

Kubiatko, M. (2010). Czech university students’ attitudes towards ICT used in science education. *Journal of Technology and Information Education, 2*(3)*,* 20–25.‏

Kubiatko, M., & Vlckova, K. (2010). The relationship between ICT use and science knowledge for Czech students: A secondary analysis of PISA 2006. *International Journal of Science and Mathematics Education, 8*(3)*,* 523–543.‏

Liu, R., Wang, L., Lei, J., Wang, Q., & Ren, Y. (2020). Effects of an immersive virtual reality-based classroom on students’ learning performance in science lessons. *British Journal of Educational Technology*, 51(6), 2034-2049.

Lui, M., McEwen, R., & Mullally, M. (2020). Learning in immersive virtual reality: Supporting student understanding of complex concepts. *British Journal of Educational Technology,* 51(6), 2181-2199.

Livingstone, S. (2012). Critical reflections on the benefits of ICT in education. *Oxford Review of Education, 38*(1)*,* 9–24.‏

Manny-Ican, A., Berger-Tikochinsky, T., & Beshan, C. (2013). Does using instructional means encourage innovative pedagogical interaction in the classroom? In A. Eshet-alkali, S. Caspi, N. Eden, J. Kalman Gary, & V.I. Yair (Eds.), *Chase conference book for learning technology studies 2013: The person studying in the technological era* (pp. 122–129). Ra'anana, Israel: The Open University. (In Hebrew)

Martinovic, D., & Zhang, Z. (2012). Situating ICT in the teacher education program: Overcoming challenges, fulfilling expectations. *Teaching and Teacher Education, 28*(3)*,* 461–469.‏

Marton, F. (1986). Phenomenography: A research approach to investigating different understandings of reality. *Journal of Thought, 21*(3)*,* 28–49.

Midgley, C., Kaplan, A., Middleton, M., Maehr, M. L., Urdan, T., Anderman, L. H., ... & Roeser, R. (1998). The development and validation of scales assessing students' achievement goal orientations. *Contemporary Educational Psychology, 23*(2)*,* 113–131.‏

Ministry of Education. (2011). *Adapting the 21st-century education system*. Jerusalem: Ministry of Education. (In Hebrew)

Nachmias, R., Mioduser, D., & Forkosh‐Baruch, A. (2010). ICT use in education: Different uptake and practice in Hebrew‐speaking and Arabic‐speaking schools in Israel. *Journal of Computer-Assisted Learning, 26*(6)*,* 492–506.‏

Nir, A., Ben-David, A., Bogler, R., & Zohar, A. (2016). School autonomy and 21st-century skills in the Israeli educational system: Discrepancies between the declarative and operational levels. *International Journal of Educational Management, 30*(7)*,* 1231–1246.‏

Pedró, F. (2006). *The new millennium learners: Challenging our views on ICT and learning*. Retrieved from https://publications.iadb.org/publications/english/document/The-New-Millennium-Learners-Challenging-our-Views-on-ICT-and-Learning.pdf ‏

Resnick, M. (2002). Rethinking learning in the digital age. In G. Kirkman (Ed.), *The global information technology report: Readiness for the networked world* (pp. 32–37). Oxford: Oxford University Press.

Sánchez, J. J. C., & Alemán, E. C. (2011). Teachers’ opinion survey on the use of ICT tools to support attendance-based teaching. *Computers & Education, 56*(3)*,* 911–915.‏

Shemesh, M., Schwartz, I., Sand, T., Freund, T., Schiffer, R., Veissenshter, I., Talmon, G., & Dreyfus, A. (2008). Matriculated matriculation exams adapted to the online learning environment in life sciences. In A. Eshet-alkali, S. Caspi, N. Eden, J. Kalman Gary, & V.I. Yair (Eds.), *Chase conference book for learning technology studies 2013: The person studying in the technological era* (pp. 207–211). Ra'anana, Israel: The Open University.

Sorgo, A., Verckovnik, T., & Kocijancic, S. (2010). Information and communication technologies (ICT) in biology teaching in Slovenian secondary schools. *Eurasia Journal of Mathematics, Science & Technology Education, 6(1), 37-46.*

Spiezia, V. (2010). Does computer use increase educational achievements? Student-level

evidence from PISA. *OECD Journal: Economic Studies, 2010*(1), 1–22.‏

Vorgan, I. (2010). *School computing: A snapshot*. Jerusalem: Knesset Research and Information Center. (In Hebrew)

Wadawi, J. K. (2013). An assessment of cooperative learning effectiveness in tourism and hospitality teaching: A case study of selected student groups at Strathmore University in Kenya. *Ecoforum Journal, 2*(1)*,* 2–18.

Wadmani, R. (2012). *Patterns of change and development in teachers’ perceptions of the meaning of teaching and learning in technology-based environments*. Pages, 54, 167–192. (In Hebrew)

Ziden, A. A., Ismail, I., Spian, R., & Kumutha, K. (2011). The effects of ICT use in teaching and learning on students’ achievement in science subject in a primary school in Malaysia. *Malaysia Journal of Distance Education, 13*(2)*,* 19–32.

Zohar, A. (2011). Towards communication with a pedagogical horizon. *Echo of Education, 86*(2), 95–98. (In Hebrew)

Zucker, A. A., Tinker, R., Staudt, C., Mansfield, A., & Metcalf, S. (2008). Learning science in grades 3–8 using probeware and computers: Findings from the TEEMSS II project. *Journal of Science Education and Technology*, 17(1), 42–48