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

# Author Biography

# Abstract

This study analyzes the effectiveness of integrating information and communication technology (ICT) into science classes of disadvantaged minority students enrolled in elementary public schools in Israel. 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 experimental 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 teacher training programs to improve technological capabilities of their trainees especially in 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

Responding to rapid technological and cultural changes in the 21st century, teaching approaches emphasizing knowledge transfer and practice have given way to innovative teaching approaches that cultivate understanding and critical thinking in a technology-integrated learning space. All over the world, information and communication technology (ICT) is being used in classrooms as a tool to improve student achievement and to promote digital literacy (Livingstone et al., 2021; Lazonder et al., 2020‏). In addition, ICT can mediate learning (Bower, 2019) and help develop Social Emotional Learning (SEL) skills that reinforce intrapersonal space, improve self-management, and contribute to perceptions of self-efficacy (Zheng & Chen, 2021; Benbenishty & Friedman, 2020).

ICT in science classes at the elementary school level has been shown to improve student attitudes and achievement (Huang, et al., 2021). Furthermore, the use of ICT, especially immersive virtual reality in science classrooms, improves student achievement and enhances emotional and social involvement (Liu et al., 2020; Cheng & Tsai, 2020). 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 (Cheng & Tsai, 2020; Huang et al., 20210).

Rohatgi et.al (2016) found a positive association between ICT self-efficacy and the use of ICT. Student self-efficacy in ICT refers to the extent to which students feel competent while using ICT in learning. Because ICT self-efficacy refers to a student’s belief in their ability to use ICT, it is expected that students with high self-efficacy in this area will choose to use ICT in their learning. Students with high ICT self-efficacy may show more perseverance in using ICT even in the face of obstacles and failure.

Park and Weng (2020) argue that any pedagogical method that integrates ICT in learning develops students’ intrinsic motivation and promotes involvement as students are fascinated by technology. Moreover, Lee et al. (2016) found that intrinsic motivation was positively related to student involvement which, in turn, was positively related to science performance. Student performance in the field of science has received increasing attention in recent years (Lai, & Leung, 2018). Moreover, recent studies have uncovered a positive relationship between integrating ICT in learning and improved student academic performance (Xiao & Hu, 2019). For example, Huang et al. (2021), in their study that comprehensively examined the relationships between student achievement in science classes and their use of ICT, found a positive relationship between student enjoyment of science learning and science performance.

To provide more information on the relationships between integrating ICT in learning and academic achievement in general, and science performance in particular, it is necessary to investigate several influential factors (Huang et al., 2021). For example, it is self-evident that motivational beliefs would be strong predictors of student self-regulation in science learning. Students with high motivation in learning science are more likely to have a positive attitude towards science and were more successful in learning science. The process of using ICT to obtain information itself can be enjoyable in itself and therefore, the need for external and internal rewards is diminished.

Chiao & Chiu (2018) found a positive relationship between ICT use and student academic achievement in deprived socioeconomic contexts while Park and Weng (2020) conducted a study that points out that student achievement depends on family income and student ability to work with ICT. In the light of this and of the positive impacts noted by ICT scholars reviewed above, we conducted a study on the effectiveness of integrating ICT in science classes for disadvantaged minority students at public elementary schools in Israel.

Specifically, we examine the effect of integrating ICT on student motivation, sense of self-efficacy, achievement, and collaboration. The focus on minority, Arabic-speaking, disadvantaged students stems from two principal concerns: first, the scarcity of research in this area (Nachmias et al., 2010), and, second, their underperformance (Abu-Asaba, 2007). In this study, we examine the effectiveness of the Ministry of Education ICT project, based on four dimensions defined by the Israeli Ministry of Education: motivation, self-efficacy, academic achievement, and student collaboration.

The aim of this initiative is the integration of ICT in teaching as a key aspect of the education system in the 21st century, alongside information and communication literacy, critical thinking, problem-solving, and communication sharing and teamwork. The goals of the initiative are to develop student motivation, collaboration in learning, self-efficacy, and to improve student achievement.

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 ICT integration in science classes in Israel is lacking, studies on integrating ICT in classes in general have been conducted more frequently (Brandes & Strauss, 2013). Although many initiatives at both the national and local levels 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 in schools are still very limited.

Despite these challenges, research based on classroom observation suggests that introducing laptops into classrooms may contribute to the adoption of innovative pedagogies as 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, computer-aided technology emphasizes divergent and multidimensional thinking and the visual illustration of complex phenomena, features necessary in science teaching (Klein, 2011). In a more recent study, Getz & Goldberg (2016) 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 (Manny-Ican et al., 2013). And the activities of the “The Center for Thinking,” 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 a great deal of pressure on teachers and administrators to meet technological requirements. Specifically, owing to the large effort invested in dealing with technology, teachers report a lack of time for significant in-person teaching.

Therefore, further research was needed to examine the effectiveness of integrating ICT in science classes, especially among underprivileged minority students attending public elementary schools in Israel. Specifically, we examined the impact of ICT integration on student motivation, self-efficacy, improvement in academic achievement, and collaboration. 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 among 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 elementary public schools in Israel in the 2018-2019 school year. Both schools are located in the same area and are classified as elementary public schools in which the curriculum is taught in Arabic. 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 was 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 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.

However, the experimental conditions could not randomly assign students into classes. Both groups were assessed at two points in time, before 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 science program that integrates an ICT-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 a digital-only interface while 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 in the control group. The students received a detailed explanation of the use of a platform that included MindCet’s ICT program in science (presented in Appendix B).

## Instruments

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 questions included in the questionnaire are designed to elicit information about the specific drivers that motivate students to put effort into their schoolwork 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-avoidance orientation.”

The internal consistency score of the questionnaire as determined in previous studies ranged from 0.71 to 0.80 (Midgley et al., 1998), In our study, it was 0.66. The score was calculated by averaging questions answered by the respondents. 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, & Eden (2001) designed a questionnaire to measure perceptions of self-efficacy, defined as students’ belief in their capacity to execute behaviors necessary for the attainment of goals. The questions are designed to measure students’ confidence in their ability and capacity to acquire new knowledge and skills. Various studies have confirmed its high content and predictive validity (Chen et al., 2001), and it has an α > 0.90.

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 respondents 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 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 (out of 100) and level for each item (according to 1-4), level of knowledge 1, Level of knowledge and understanding 2, Level of understanding 3 and Level of understanding and analysis 4. Examples of the types of questions posed include: “Write two examples of adaptation in the body structure of an animal to the environment.” This question examined the level of knowledge and understanding of the students where the weight was 6 points and the level was 2. The following question “For whom is breathing an essential need? Circle the most correct answer.” examined the level of knowledge of the students (weight-3 points; level -1). “The common properties of liquids and gases are…” (weight-3 points; level-3), “Animals breathing with gills belong to class: …” (weight -5 points; level-4).

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 measurements 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). 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. 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 & Pischke, 2008). In our case, the treatment group refers to the students using 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.

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, a DID equation was formulated: Eq. 1 – *G(i)=a+β\_1 C+β\_2 T+β\_3 I+e.[[1]](#footnote-2)*

To test the hypothesis, expecting a greater increase in motivation among fifth-graders at elementary public schools with ICT integration in science classes as compared to that among their peers studying in the traditional manner, another DID equation was formulated: Eq. 2 – *M(i)=a+β\_1 C+β\_2 T+β\_3 I+e.[[2]](#footnote-3)*

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.[[3]](#footnote-4)*

The first, in the form of an algebraic- graphic table, as discussed in the hypothetical example above and, the second, by employing regression analysis. -in-differences

# Results

The "treatment" was applied to one group (ICT-integrated science classes) but not to the other (traditional learning without ICT integration). We estimated the difference-in-differences using 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. 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 show a significant difference of 8.13.

In conclusion, the mean score of student achievement in the experimental group increased after the intervention (9.81) as it 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 results in Table 2 show 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 This indicates a significant difference in the change in achievement between the programs. 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 in the DID calculation described in Equation 2. The table shows the average motivation score.

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 in the group which studied the ICT program, the level increased slightly (from 2.28 to 2.26). The difference between the average motivation score in the traditional program and the 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 (respectively). 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.

The above results are confirmed in Table 4, which reports the regression findings following 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 | | | |  |  |

Table 4 also shows 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. 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.

Identical to the measurements for achievement discussed above, the measurements for motivation 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 1 and 2.

Table 5 presents the findings of the study that arose 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 self-efficacy.

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.

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 | | | |  |  |

Table 6 shows 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. 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 utilized. 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, the results of the observations in the traditional learning program were mixed, suggesting that collaboration among 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, in 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 among group members, two observations reported good communication among most students during the group tasks, whereas one observation noted good communication in only some of the groups. Regarding students’ self-confidence during group work, only some of the students demonstrated self-confidence, especially the high-achieving ones who received encouragement.



# Discussion

The purpose of this study was to examine the effectiveness of integrating ICT in science classes. 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 integrating ICT in learning improves student achievement (Xiao & Hu, 2019) and that ICT integration is effective at improving achievement in science and scientific literacy (Huang, et al., 2021).

Our findings on the relationship between integrating ICT in learning and student collaboration align with previous research that showed ICT-integrated learning expands student opportunities for communication and collaboration, supports their ability to express themselves, and increases their willingness to connect with other students (Cheng & Tsai 2020; Huang et al., 2021). 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 contributed to improved academic achievement and ICT supported learning through discussion. Our observations indicate that ICT use indeed contributed 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 there were no significant differences in the motivation between the examined groups, that is, the difference in the students’ motivation in the treatment group where ICT was integrated into the learning process and in the control group—traditional learning was not statistically significant. This finding does not align with the literature. For example, Park & Weng (2020) argued that any pedagogical method that integrates ICT in learning develops students’ intrinsic motivation and promotes involvement, as they are fascinated by technology.

There are two possible explanations for this discrepancy. The first explanation is based on the gap between the ICT program’s design and its implementation (Brandes & Strauss, 2013). Hence, 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.

Our findings on the relationship between integrating ICT in learning and students’ self-efficacy also do not align with previous research. While some recent studies have found a positive relationship between the use of ICT and self-efficacy (Rohatgi et al., 2016; Venkatesh & Davis, 2000), our study found no significant difference. One explanation may be the gap between the potential of ICT and its actual use, preventing the realization of some of the program’s goals, 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 might also impede the development of self-confidence. According to this explanation, when students do not receive the teacher feedback they expect in the learning process, even though they may assimilate the material taught and improve their achievement, they may still not feel confident, and therefore not their sense of self-efficacy is not improved.

In line with these explanations, it is not surprising that the present study, as in previous research, finds that the ICT program improves student achievement in the sciences. In addition, apart from enhancing the 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.

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1. 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 [↑](#footnote-ref-2)
2. Where *M* is motivation of student. [↑](#footnote-ref-3)
3. Where SE is the self-efficacy of student. [↑](#footnote-ref-4)