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Impact of Using ICT for Learning Purposes on Self-Efficacy and Persistence: Evidence from Pisa 2018

Rikito Hori [1] and Makoto Fujii [2,*]

[1] Elementary School, Kansai University, Takatsuki 569-1098, Japan; r.hori@kansai-u.ac.jp
[2] Division of Health Science, Graduate School of Medicine, Osaka University, Suita 565-0871, Japan
* Correspondence: m.fujii@sahs.med.osaka-u.ac.jp

Abstract: In recent years, the use of information and communication technology (ICT) has meant that learning is no longer limited to the school. In order to achieve Sustainable Development Goal (SDG) goal 4, that is, to ensure quality education for all, to make educational resources and online learning are indispensable, and to access these resources anytime, anywhere through the Internet. In addition, the global pandemic of COVID-19 has made online education more necessary than ever before. Where and how ICT is used may have an impact on the components of motivation, such as self-efficacy and persistence. In this study, we quantified the impact of ICT utilization on the two components of self-efficacy and persistence. The effects of ICT use on both components were analyzed from the data taken from the 2018 Program for International Student Assessment (PISA) administered to 15-year old students. The results revealed that students who frequently utilized ICT for the purpose of out-of-school learning, particularly for activities related to school projects, exhibited significantly higher levels of self-efficacy and persistence. The frequency of ICT usage for in-school learning revealed no effect on any of the two above components. In addition, utilization of ICT for recreational purposes outside of school showed significantly lower values in the area of persistence. These results indicate that it is important to set tasks that provide a continuum of ICT use, both in and out of school, in order to motivate learners. This has important implications for the design of learning in online education. Furthermore, it suggests that teachers should design exploratory type lessons that focus on strengthening students' desire to learn outside of class.

Keywords: teaching/learning strategies; media in education; interdisciplinary projects; lifelong learning; 21st century abilities

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1. Introduction

Recent advances in technology have made it easier to access educational resources online, giving learners more freedom and choice [1–4].

In 2012, 96% of 15-year-old students in countries involved in the Organization for Economic Co-operation and Development (OECD) reported having a computer at home [5]. On average across OECD countries in 2018, there was almost one computer available at school for educational purposes for every 15-year-old student [6]. In line with the proliferation of digital devices, access to Internet services has come to be regarded as infrastructure, so much so that it has been declared a basic human right [7]. In public education as well, there has been a massive influx of new educational technologies, as more schools are assigning laptops and other devices to every student [8,9]. However, if the focus is shifted from OECD nations to developing ones, African countries are noticeably lagging behind the rest of the world in information and communication technology (ICT) and infrastructure development [10], and there still exist millions of people who are unable to fully access these tools [11–13].

The gap between those who possess access to ICT tools and those who do not is referred to as the "digital divide", a concept that describes the inequality in the use of ICT

tools and the Internet [3,14]. Recently, the ratio of computers to students in schools has been increasing, even in developing countries [15]. This consequentially widens the digital divide, due to the lack of Internet access and computer availability, as well as the inequality in acquiring digital skills. The latter is strongly related to the level of education [14,16].

The Sustainable Development Goals (SDGs) have been established for governments throughout the world to pursue seventeen specific areas such as efforts to end poverty and hunger, promote citizens' well-being and education, reduce inequality, and protect the planet's environment [17]. Related to education, the fourth goal calls for the guarantee of "quality education" to all and for learners to have the knowledge and skills necessary to promote sustainable development [18]. According to 2014 estimates, more than one in three elementary school children worldwide (about 250 million) drop out from school without learning essential skills such as reading, writing, or even simple arithmetic. In order to help reach these children, ICT is necessary to harness information and knowledge for the development of the future of these children as well as for the development of global industries [4,19,20].

The surge of ICT has led to the rapid spread of e-learning and the emergence of various online teaching and learning models [17]. Digital technologies have made it possible to share copyrighted works anytime and anywhere, while the open license framework has made such sharing legal [14]. Such use of ICT has made it possible to expand access to educational resources of all kinds [21], not to mention improving and diversifying learning pathways. The result is the improvement in the quality of learning and in reaching out to the vulnerable and underserved groups, such as rural youth and adults, women, youths who are not attending school, and people with disabilities [4,20]. In fact, the United States introduced school e-learning programs as a way to ensure equitable educational opportunities for all students [22,23]. In Sudan, the "Can't Wait to Learn" initiative uses solar-powered tablets and interactive self-study software to provide children who are not attending schools access to Sudan's official primary-level mathematics curriculum [4].

With respect to online education, MOOCs, or massive open online courses, have large enrollments that are conducive to educational research since they are free to anyone in the world [24]. In fact, learners see MOOCs as an opportunity to learn at their own pace regardless of where they reside [25]. The global pandemic of COVID-19 has caused many countries to stop face-to-face classes from the early stages. UNESCO statistics show that as of March 2021, schools in more than 205 countries have been affected [26]. Distance learning is said to be the only solution, and online education is needed more than ever [27]. It is worth noting that one of the common challenges of these online education is the high dropout rate [25,28–34]. This is due to the nature of online education, that is, the courses are unsupervised and self-paced, and the learning itself is isolated [29,35–38]. The enrolled students may also experience anxiety stemming from the difficulty in the usage of the technology [39]. These factors may reduce students' motivation and make it difficult for them to continue learning.

It has been suggested that motivation plays an important role in the learning process, contributing to either increased persistence or the abandonment of learning [34]. In online and distance education courses, self-efficacy has been associated with various aspects of performance and plays an important role in participation and persistence in learning [40–42]. Self-efficacy is considered to be the most useful of the motivation constructs developed in recent years and can be understood as beliefs about the degree of confidence that one can complete a particular task or achieve a chosen goal [43]. Compared to students who doubt their abilities, there is evidence that students with self-efficacy are more likely to participate, to work harder, to persist, and to have less adverse emotional reactions when faced with difficulties [44–46]. In other words, students with higher self-efficacy are more likely to be persistent and more likely to engage in online education. This "persistence", referred to as the construct perseverance, is the willingness of learners to complete the learning tasks they have initiated. Examples include completing an enrolled

course or earning a degree [47,48]. Perseverance can also be defined as the potential to continue to strive for problem-solving in the face of difficulties [49].

Bandura, in his framework of self-efficacy, identifies past personal experience with a given task as perhaps the strongest predictor of self-efficacy [44]. Meaning that if a student engages in a particular task, and gains positive mastery experiences, then self-efficacy is also strengthened [43]. This has been stated to be true for both general self-efficacy [50] as well as computer self-efficacy [51–53]. Hence, how ICT is used in learning and the subsequent experiences of the student may make a difference in the way self-efficacy is perceived.

There have been various studies on the effects of using ICT [54–60]. It remains to be seen whether increased access to ICT at home and at school will improve or hinder students' academic performance [3]. Since studies aimed at investigating the effects of ICT use without specifying the extent and type of ICT use have produced equivocal results [61], more research is thus necessary to focus on and analyze where and for what purpose ICT is being used. Specifically, one of the factors that needs to be taken into account is the location of ICT use, namely, at school versus at home [62]. Skryabin et al. suggest that ICT use in the classroom compared to at home have different impacts on student learning [62]. In addition, Petko et al. found that there is a positive correlation between students' ICT usage at home with their math, science, and reading skills [63]. Conversely, there is a reasonable negative correlation between students' ICT usage for recreational purposes at home and their academic performance. This leads us to consider two perspectives on the purpose of ICT use: recreation or learning.

Much research has been undertaken on how the use of digital devices affects self-efficacy within the limited scope of self-efficacy for ICT [3,56,64]. Prior research has shown that the more frequent the use of ICT, the greater the self-efficacy for ICT [51,64]. In particular, the frequency of ICT use outside of school has been shown to be influential, but this is limited to recreational purposes (use of videos and social media). Additionally, it has little impact on the frequency of use for learning purposes [64]. Previous studies also have not examined the impact on self-efficacy beyond ICT.

The current study sought to clarify the impact of ICT use based on two factors: self-efficacy and persistence. Specifically, we quantified the effects of self-efficacy (1) from ICT usage inside and outside of school for recreational and learning purposes, and (2) from problem solving not limited to ICT and persistence. To the best of our knowledge, no previous studies have analyzed the impact of the use of digital devices on motivation from multiple perspectives of self-efficacy and persistence. We believe that this is an important issue in the area of examining ICT technology for education.

2. Material and Methods

2.1. Study Design

This study was a cross-sectional study using a large international dataset.

2.2. Database and Selection of Participants

We used data from the Programme for International Student Assessment (PISA), which is an international standardized assessment administered to 15-year-olds attending schools. PISA assesses domains such as reading ability, mathematical ability, and scientific literacy. In addition to content assessments, PISA also includes surveys of students, parents, and schools, containing questions related to students' and parents' backgrounds, and students' attitudes toward reading and ICT. Data from all students included in the PISA 2018 were analyzed. As shown in Table 1, we focused on and analyzed 19 questions regarding self-efficacy, persistence, and ICT utilization. Since the PISA survey items vary from country to country, we included only those subjects in which all 19 questions data were answered in the analysis. The total number of subjects was 612,004 in 77 countries and regions, and the number of subjects included in the final analysis was 409,803 in 52 countries and regions.

Table 1. Description of the question items in the PISA data.

Description	Question Number	Question Text	Summary
Self-efficacy for ICT, mean (SD)	IC014Q08NA	I think I can solve any problems with digital devices.	2.90 (0.78)
Self-efficacy not limited to ICT, mean (SD)	ST188Q07HA	I can usually find a solution when faced with difficulties.	3.02 (0.65)
Persistence-A, mean (SD)	ST182Q04HA	Once I start a task, I persist until it is finished.	2.93 (0.77)
Persistence-B, mean (SD)	ST182Q06HA	If I am not good at something, I would rather keep struggling to master it than move on to something I may [...]	2.86 (0.81)
Available using at home, n (%)	IC001Q01TA-03TA	Available for you to use at home: desktop computers, portable laptops, notebooks, or tablet computers.	237,055 (69.56)
Available using at school, n (%)	IC009Q01TA-03TA	Available for you to use at school: desktop computers, portable laptops, notebooks, or tablet computers.	227,749 (74.01)
ICT use for recreational purposes			
Playing one-player games, mean (SD)	IC008Q01TA	Use digital devices outside of school: playing one-player games.	2.60 (1.42)
Participating in social networks, mean (SD)	IC008Q05TA	Use digital devices outside of school: participating in social networks (e.g., Facebook, MySpace).	3.94 (1.38)
Browsing the Internet for fun, mean (SD)	IC008Q08TA	Use digital devices outside of school: Browsing the Internet for fun (such as watching videos, e.g., YouTube).	4.04 (1.19)
learning purposes that have continuity with school lessons			
Browsing the Internet for schoolwork outside of school, mean (SD)	IC010Q01TA	Use digital devices outside of school: Browsing the Internet for schoolwork [...]	2.86 (1.17)
Browsing the Internet to follow up lessons outside of school, mean (SD)	IC010Q02NA	Use digital devices outside of school: browsing the Internet to follow up lessons, e.g., for finding explanations.	2.71 (1.22)
learning purposes that do not have continuity with school lessons			
Learning apps or websites outside of school, mean (SD)	IC010Q11HA-12HA	Use digital devices outside of school: using learning apps or learning websites on a computer or a mobile device.	2.38 (1.27)
Browsing the Internet at school, mean (SD)	IC011Q03TA	Use digital devices at school: browsing the Internet for schoolwork.	2.63 (1.31)
Learning apps or websites at school, mean (SD)	IC011Q10HA	Use digital devices at school: using learning apps or learning websites.	2.06 (1.28)

ICT: Information and communication technology.

2.3. Definition and Questions Used in the Analysis

2.3.1. Self-Efficacy

In the current study, self-efficacy was divided into self-efficacy for ICT and self-efficacy not limited to ICT. The following two statements to the questionnaire in the PISA study were used: "I think I can solve any problems with digital devices", and "I can usually find a solution when faced with difficulties". These statements consisted of a 4-step Likert scale, and we used the original values without coding.

2.3.2. Persistence

The dataset from the following statement from the PISA study was used to measure persistence: "Once I start doing a task, I finish it", and "I'm the one who works hard at something I'm not good at until I can do it, instead of running away from something I'm not good at". These questions used the original values as well.

2.3.3. ICT Usage

We analyzed the location of ICT usage (whether if it was used inside or outside of school) and the purposes for which it is used (recreation and learning) separately. In addition, learning purposes were separated into two categories: those that have continuity with school lessons and those that do not. These questions used the original values as well.

2.3.4. Availability for Students to Use ICT Devices at Home or School

Questions regarding the availability of ICT devices at each student's school or home are investigated in three stages: "owned and available", "owned but not available", and "non-owned". These questions ask the ownership and use of multiple devices in separate questions. We coded those who answered that they own and use at least one of them in any of the questions as the variables, "available using at home" and "available using at school" (Table 1).

2.4. Ethics Approval

All data used in this study are available on the web, and the study was not subject to ethical review.

2.5. Statistical Analysis

We used multi-level logistic regression to clarify the relationship between self-efficacy not limited to ICT, self-efficacy for ICT, persistence, and using ICT. The PISA dataset contains nested data. Our purpose is not to reveal differences between nations or institutions. Therefore, information on nations and facilities was not treated as a fixed effect. However, there is a need to properly control unobserved heterogeneity in nations and institutions. Therefore, we controlled unobserved heterogeneity by treating variables related to states and facilities as random effects. Two levels of information were set up: national information and school information. For the construction of multivariate models including covariates, variables related to self-efficacy and persistence were selected based on previous studies [1,40–44,47–53,64]. The effect of each variable was reported as an effect size. Effect size is indicated by a regression coefficient relative to zero. A positive effect size indicates an effect that promotes self-efficacy and persistence, and a negative effect indicates an effect that suppresses it. The significance level was 5% on both sides, and all statistical analyses were performed using SAS 9.4 (SAS Institute, Cary, NC, USA).

3. Results

The number of students with access to a desktop computer, portable laptop, notebook, or tablet computer at home was 237,055 (69.56%) and the number with access at school was 227,749 (74.01%). A total of 275,656 students responded positively to the question "Once I start a task, I persist until it is finished", with an average score of 2.93 (standard deviation [SD]: 0.77). A total of 261,288 students responded positively to the question "if I am not good at something, I would rather keep struggling to master it than move on to something I may", with an average score of 2.86 (SD: 0.81). A total of 301,876 students responded positively to the question "When I'm in a difficult situation, I can usually find my way out of it" with an average score of 3.03 (SD: 0.69). A total of 312,323 students responded positively to the question "I usually manage one way or another", with an average score of 3.02 (SD: 0.65).

3.1. Relationship between Self-Efficacy Using ICT and Self-Efficacy Not Limited to ICT

Figure 1 and Table 2 shows the results regarding the relationship between ICT use and self-efficacy not limited to ICT. The variable with the largest effect size was using digital devices to browse the internet for schoolwork, with an effect size of 0.024 ($p < 0.0001$), followed by availability of a desktop computer, portable laptop, notebook, or tablet computer at home, with an effect size of 0.024 ($p < 0.001$).

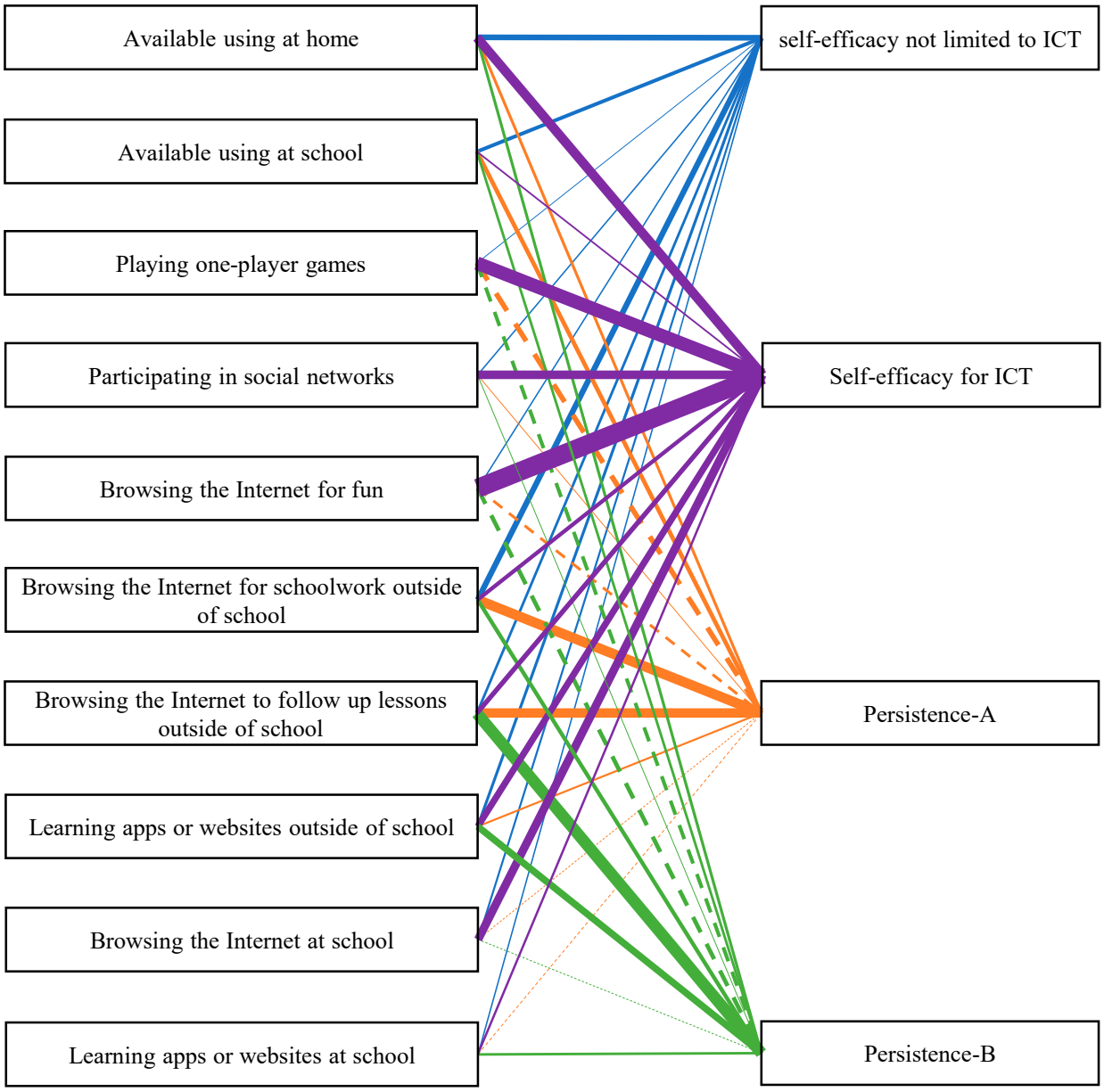

Figure 1. Relationship between self-efficacy not limited to ICT, self-efficacy for ICT, persistence-A, and persistence-B, and using ICT, in a multivariable generalized linear mixed model. The line thickness shows the magnitude of the effect size, and the dashed line shows the negative effect.

3.2. Relationship between Self-Efficacy for ICT and Using ICT

Table 2 shows the results regarding the relationship between ICT use and self-efficacy for ICT. The variable with the largest effect size was using digital devices outside of school for playing one-player games, with an effect size of 0.079 ($p < 0.0001$), followed by availability of a desktop computer, portable laptop, notebook, or tablet computer at home, with an effect size of 0.056 ($p < 0.001$). High frequency of use related to entertainment and games was more influential than ICT use related to academic work.

Table 2. Relationship between self-efficacy not limited to ICT and self-efficacy for ICT, and using ICT, in a multivariable generalized linear mixed model.

Variable	Self-Efficacy not Limited to ICT	Self-Efficacy for ICT
	Effect Size (95%CI)	Effect Size (95%CI)
Available using at home	0.024 (0.021 to 0.027)	0.039 (0.035 to 0.042)
Available using at school	0.016 (0.012 to 0.019)	0.007 (0.003 to 0.010)
Playing one-player games	0.004 (0.002 to 0.006)	0.056 (0.054 to 0.058)
Participating in social networks	0.006 (0.003 to 0.008)	0.036 (0.034 to 0.039)
Browsing the Internet for fun	0.006 (0.003 to 0.009)	0.079 (0.076 to 0.082)
Browsing the Internet for schoolwork outside of school	0.024 (0.021 to 0.028)	0.017 (0.013 to 0.021)
Browsing the Internet to follow up lessons outside of school	0.011 (0.008 to 0.015)	0.020 (0.016 to 0.024)
Learning apps or websites outside of school	0.012 (0.009 to 0.015)	0.028 (0.025 to 0.032)
Browsing the Internet at school	0.008 (0.005 to 0.010)	0.035 (0.032 to 0.038)
Learning apps or websites at school	0.006 (0.003 to 0.009)	0.009 (0.006 to 0.012)

3.3. Relationship between Persistence and Using ICT

Table 3 shows the results regarding the relationship between ICT use and persistence-A. The variable with the largest effect size was using digital devices for browsing the internet for schoolwork, with an effect size of 0.042 ($p < 0.0001$), followed by availability of digital devices outside of school for browsing the internet to follow-up lessons, with an effect size of 0.039 ($p < 0.001$). The variable with the largest negative effect size was using digital devices outside of school for playing one-player games, with an effect size of −0.022 ($p < 0.0001$), followed by availability of digital devices outside of school for browsing the internet for fun, such as watching videos, with an effect size of −0.012 ($p < 0.001$).

Table 3. Relationship between persistence-A and using ICT in multivariable generalized linear mixed model.

Variable	Persistence-A Effect Size (95%CI)
Available using at home	0.012 (0.008 to 0.015)
Available using at school	0.018 (0.014 to 0.022)
Playing one-player games	−0.022 (−0.024 to −0.02)
Participating in social networks	0.003 (0 to 0.006)
Browsing the Internet for fun	−0.012 (−0.015 to −0.009)
Browsing the Internet for schoolwork outside of school	0.042 (0.038 to 0.046)
Browsing the Internet to follow up lessons outside of school	0.039 (0.035 to 0.043)
Learning apps or websites outside of school	0.008 (0.005 to 0.012)
Browsing the Internet at school	−0.002 (−0.005 to 0.001)
Learning apps or websites at school	−0.004 (−0.007 to −0.001)

Table 4 shows the results regarding the relationship between ICT use and persistence-B. The variable with the largest effect size was using digital devices outside of school for browsing the Internet to follow up lessons, with an effect size of 0.049 ($p < 0.0001$), followed by availability of digital devices outside of school using learning apps or learning websites on a computer or mobile device, with an effect size of 0.029 ($p < 0.001$). The variable with the largest negative effect size was using digital devices outside of school for browsing the Internet for fun, such as watching videos, with an effect size of −0.018 ($p < 0.0001$), followed by availability of digital devices outside of school for playing one-player games, with an effect size of −0.016 ($p < 0.001$).

Table 4. Relationship between persistence-B and using ICT in multivariable generalized linear mixed model.

Variable	Persistence-B Effect Size (95%CI)
Available using at home	0.012 (0.008 to 0.016)
Available using at school	0.011 (0.007 to 0.014)
Playing one-player games	−0.016 (−0.018 to −0.014)
Participating in social networks	0.000 (−0.003 to 0.003)
Browsing the Internet for fun	−0.018 (−0.022 to −0.015)
Browsing the Internet for schoolwork outside of school	0.017 (0.012 to 0.021)
Browsing the Internet to follow up lessons outside of school	0.049 (0.045 to 0.054)
Learning apps or websites outside of school	0.029 (0.025 to 0.032)
Browsing the Internet at school	−0.002 (−0.005 to 0.001)
Learning apps or websites at school	0.011 (0.007 to 0.014)

4. Discussion

In the current study, we quantified the impact of "inside of school" and "outside of school" ICT use, "recreational purposes" and "learning purposes", on "self-efficacy for ICT" and "self-efficacy not limited to ICT", as well as on persistence.

ICT usage was significantly associated with self-efficacy. "ICT use for recreational purposes" had a strong impact on "self-efficacy for ICT". "Self-efficacy for ICT" was found to be higher among participants with more frequent ICT use. Experience of ICT use is reported to influence confidence in technology use and beliefs about what one can do with ICT [52,64], consistent with the findings of the current study.

The use of ICT for learning purposes, particularly outside of school, was found to have a strong impact on "self-efficacy not limited to ICT". This finding has not previously been reported in the context of self-efficacy not limited to ICT, and we believe that considering the quality of ICT use, rather than the frequency of ICT use, may lead to better outcomes for students [65].

In addition, ICT use was significantly associated with persistence. The results revealed that "ICT use for recreational purposes" was negatively associated with persistence, whereas "ICT use for learning purposes" was positively associated with persistence. From these results, it can be said that although both recreational and learning purposes of ICT use outside of school have a positive impact on self-efficacy, "ICT use for recreational purposes" has a negative impact on persistence, and therefore, it is better to develop a learning environment where the frequency of "ICT use for learning purposes" can be increased.

Among the items associated with learning purposes, those that have continuity with school lessons exhibit the highest levels of self-efficacy and persistence. Self-efficacy and persistence are the components comprising motivation [1,40–44,47–53,64]. The use of ICT outside of school to solve learning problems within the classroom ensures students' freedom of self-determination, creating an interactive learning experience for students. These experiences increase intrinsic motivation [66].

Based on previous studies of various approaches, such as the flipped classroom, project-based learning, and blended learning methods, in-school learning was found to be contiguous with out-of-school learning. Students are given choices on how to solve some problems [67]. This facilitates independent learning as well as independent learning at each stage of the learning process. The use of technology to solve problems by providing access to devices is thought to increase students' motivation to learn outside of school, consistent with the current study [54,57,68–71].

The use of ICT for learning purposes inside of school did not have a strong influence on the two constructs we examined. Previous research has suggested that the use of digital devices inside of school is not effective because students are controlled and supervised by teachers in schools and the time designated for ICT use is clearly divided, meaning that students are not given freedom when using devices in school [52,64].

In a one-to-one learning environment, traditional teaching methods are typically still applied, often limiting the use of ICT to the classroom. We propose that it is important to change the learning experience in the classroom from a single subject to an interdisciplinary approach, transforming the learning experience into an interactive one [52,57,72,73].

Low learner satisfaction has been identified as a major factor in dropout in online education, with learner-content interaction being the strongest predictor [74]. The results suggest that in online education, instructional designers should pay attention to content design and the selection of appropriate delivery technologies. Geng et al. (2019) propose self-directed learning, which emphasizes students' autonomy, including goal setting and choice [75]. The course design, including the sequence of materials and methodology, should be modified to increase engagement [25] and encourage continuous ICT use while learners independently self-select their problem-solving methods [27].

The current study involved several limitations. First, because this study was a cross-sectional survey using a questionnaire, causal relationships cannot be inferred. Second, because the data were from an existing survey, the questions could not be tailored to the purpose of the study. However, a major strength of the study is that the data were from a large-scale global survey with high reliability.

5. Conclusions

Learning purposes that have continuity with school lessons had the strongest impact on self-efficacy and persistence. This indicates that even if the place of learning is changed, spontaneous ICT use for problem solving can have a positive impact on self-efficacy and persistence, as well as increase motivation. This has important implications for the way online education is designed for learning. With the pandemic of COVID-19, online teaching has become even more significant. More than ever, it is important to rethink the design of online courses and learning environments so that learners are motivated to use ICT continuously through problem solving. It is therefore necessary for instructors to design lessons that promote students' use of ICT through freedom of choice and increasing their intrinsic motivation. Furthermore, we believe that this class design is the key to achieve SDG Goal 4, "Ensure access to quality education for all". Up to now, the focus has been on the content of online education, as well as its ease and convenience. Finding factors that may improve the quality of online education can be very beneficial. Future research should focus on "how to learn in online education" rather than "what to learn in online education". In online education, it is necessary to investigate the purpose of ICT use and how it affects self-efficacy and persistence compared to offline education.

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