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The relationship between the age at first computer use and students' perceived competence and autonomy in ICT usage: A mediation analysis

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ABSTRACT

Knowledge and skills with information and communications technology (ICT) usage are an essential part of modern life. In recent years, the age at which children have their first contact with ICT and first use of ICT has been decreasing. This can significantly affect the development of their digital literacy. This study investigates the relationship between the age at which children start using a computer and the degree of their perceived ICT competence and autonomy at the age of fifteen. It proposes a multiple mediator model within which the investigated relationship is mediated by ICT usage, ICT interest, and the degree to which ICT is a part of students' everyday social interactions. The model is then tested using data from 21 European OECD countries. The test results show that children who start using a computer at a later age (after the age of seven) demonstrate significantly lower ICT competence and ICT autonomy at the age of fifteen. The results of the mediation analysis suggest that the degree of ICT usage in the home environment for school purposes or activities seems less significant to the development of ICT competence and ICT autonomy than other studied ICT-related variables.

1. Introduction

The omnipresence of information and communications technology (ICT), which plays an important role in all aspects of human life, is a basic characteristic of modern society. Knowledge and skills related to modern ICT usage have thus become an integral part of education. The ability to use digital technology efficiently, independently, and responsibly is considered to be a key prerequisite for successfully integrating people into both society and the economy (European Commission, 2007; Poynton, 2005; Spante, Hashemi, Lundin, & Algers, 2018). One of the key tasks of contemporary schools is the development of digital literacy[1] (Erstad, 2011; Lankshear & Knobel, 2008; Sefton-Green, Nixon, & Erstad, 2009; Tsitouridou & Vryzas, 2011), which is a part of a larger framework of "21st century skills" (Binkley et al., 2012).

However, school and formal education present only one environment in which young people can acquire and develop their digital literacies. In fact, research suggests that the development of digital literacy also takes place in the form of informal learning at home, among peers, and in other, out-of-school contexts (Arnseth, Erstad, Juhaňák, & Zounek, 2016; Erstad, 2012; Fraillon, Ainley, Schulz,

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[1] In this context, some authors tend to use the plural form, i.e. *digital literacies*, to emphasize that this is not a single specific literacy. There are a number of other denotations, such as *computer and information literacy* (Fraillon et al., 2014; Katz & Macklin-Smith, 2007), *media literacy* (Erstad, 2010), and the more or less collective term, *new literacy* (Coiro, Knobel, Lankshear, & Leu, 2008; Knobel & Lankshear, 2014).

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Friedman, & Gebhardt, 2014). As access to technology and the internet becomes generally universal in many countries (OECD, 2017a), children are starting to use digital technology at ever younger ages (Chaudron, 2015; Chaudron, Di Gioia, & Gemo, 2018; Holloway, Green, & Livingstone, 2013). This raises a number of questions regarding how the use of ICT at an early age projects into the life and development of children and in what manner their development is affected by digital technology. This field still has many unanswered questions. One reason for this phenomenon is the fact that the use of technology by very young children has been outside of the focus of attention of researchers, especially in comparison to older children or adolescents (Staksrud, Livingstone, Haddon, & Ólafsson, 2009; Ólafsson, Livingstone, & Haddon, 2014). Even less attention has been dedicated specifically to the relationship between ICT usage at a young age and the subsequent development of digital competence of children and young people. Nevertheless, Chaudron et al. (2018), on the basis of extensive qualitative research across European countries, published the major discovery that children's ability to use ICT develops from a very young age in the home environment and that this period is absolutely essential for the development of children's digital competence.

With this study, we would like to contribute to a deeper understanding of the relationship between the digital competence of fifteen-year-old students and the time at which they started using ICT. Specifically, we will focus on the relationship between the age at which children start using a computer and the degree of their perceived competence and autonomy in ICT usage at a later age. Using data from the Program for International Student Assessment (PISA) 2015, which provides representative samples of fifteen-year-old students in dozens of countries around the world, we primarily aim to determine: (1) the extent to which the development of the perceived ICT competence and autonomy of students is affected by both the school and out-of-school environments; (2) the relationship between the age when computers are first used and the degree of perceived ICT competence and autonomy of students at the age of fifteen; (3) whether this relationship is mediated by other relevant ICT-related variables; and (4) how the investigated relationship differs across European OECD countries.

2. Background

2.1. ICT competence and autonomy in using ICT

The main concepts this study focuses on are ICT competence and ICT autonomy, which are inevitably connected to the skills and abilities of digital technology use. Existing research features various denotations which refer to ICT competence or generally the competence to use digital technology in some manner. Some authors use the term *digital competence* (Calvani, Fini, Ranieri, & Picci, 2012; Erstad, 2008); others prefer to write of related *literacies* or *skills* (Griffin, McGaw, & Care, 2012). The common feature of all these denotations is their tendency to connect digital technology with the skill or ability to use the various technologies (Ferrari, 2012; Hatlevik, Throndsen, Loi, & Guðmundsdóttir, 2018). Although it could be argued that there are larger or smaller differences between the individual terms, they can be considered synonymous in their basic meaning. The term *ICT competence* can be generally understood as the ability to use information and communications technology (Aesaert, van Braak, van Nijlen, & Vanderlinde, 2015; Calvani et al., 2012; Hatlevik & Christophersen, 2013).

The existing research has applied two basic methodological approaches to measuring ICT competence: indirect and direct measurement. The approaches seeking direct measurements usually use some form of direct monitoring while the subject performs an ICT-related task or they measure ICT competence using a performance test. In contrast, indirect measuring methods most often use some form of self-evaluating one's own ICT-related knowledge and abilities, usually referred to as *perceived ICT competence* (Aesaert & van Braak, 2015; Litt, 2013). Even though the specific conceptualization of perceived ICT competence can differ among individual research projects, two main perspectives can be identified in the published works. In the first perspective, the ability or competence at using ICT is conceptualized using the term *self-efficacy*, a central concept of Bandura's social cognitive theory (Bandura, 1986, 1997). In the context of digital technology, *ICT self-efficacy* is generally defined as an individual's conviction regarding their own ability to use ICT (Aesaert, Voogt, Kuiper, & van Braak, 2017; Hatlevik et al., 2018; Rohatgi, Scherer, & Hatlevik, 2016). Among other research and studies, the concept of ICT self-efficacy has been used as part of the International Computer and Information Literacy Study (ICILS) 2013 (Fraillon et al., 2014). In the second perspective, the basis for conceptualizing perceived ICT competence can be found in the self-determination theory (Deci & Ryan, 2000; Ryan & Deci, 2000). In this approach, which is also the basis of this study, perceived ICT competence is conceptualized as an individual's perception of their own knowledge about ICT and about how to use it (Christoph, Goldhammer, Zylka, & Hartig, 2015; Goldhammer, Gniewosz, & Zylka, 2016; Zylka, Christoph, Kroehne, Hartig, & Goldhammer, 2015). Here, the perceived competence is thus understood as a "self-concept" defined as knowledge and perceptions about oneself in achievement situations that are affected by past experiences (Byrne, 1996). An "ICT Familiarity Questionnaire" was created following this approach to be incorporated in the PISA 2015 (Kuger, Klieme, Jude, & Kaplan, 2016; OECD, 2017a, 2017b).

In the context of the PISA 2015, perceived ICT competence is understood as one of the cognitive-motivational factors forming a multi-faceted construct denoted as "ICT engagement" (Christoph et al., 2015; Goldhammer et al., 2016; Zylka et al., 2015). According to these authors, ICT engagement includes perceived ICT competence and also perceived ICT autonomy, which reflects the individual's perceived control and self-directedness in ICT-related activities (Goldhammer et al., 2016). Autonomy in ICT usage can be understood as the feeling of control in ICT usage and as part of initiating ICT-related activities with regard to one's own goals and interests. In this context, we believe that ICT autonomy is most definitely connected to ICT competence, i.e. that a certain degree of ICT competence is a necessary prerequisite in order to use digital technology autonomously. Nevertheless, the topic of autonomous ICT usage is represented disproportionately less in specialized literature and research. For this reason, this study pays equal attention to both perceived ICT competence and perceived autonomy in ICT usage.

2.2. Development of ICT competence and early computer use

The development of ICT competence in students is traditionally addressed in the context of school and formal education. However, recent studies suggest that students use modern technology much more often in the home environment than in the school (Eurydice, 2011; Wastiau et al., 2013). Moreover, family background is significantly connected to the digital competence level of students (Fraillon et al., 2014; Hatlevik et al., 2018; Hatlevik, Ottestad, & Throndsen, 2015). The role of the family environment in developing ICT competence and autonomy is further amplified by the fact that the age at which children start to use digital technology and the internet keeps decreasing (Ólafsson et al., 2014). It is currently not unusual for children to regularly encounter ICT before their first day of school (Johnson, 2010; Marsh, Hannon, Lewis, & Ritchie, 2017; O'Hara, 2011). Thus, an increasing number of children have their first experiences with ICT and start to develop their skills in using it within the family and the home environment or the pre-school education environment.

Activities connected to ICT usage in school and in the home environment tend to differ rather significantly. Murphy and Beggs (2003) state that at school, activities are controlled and overseen by the teacher and the time designated for ICT usage is usually clearly delimited. In the home environment, children are more often free to decide the activities they want to do using ICT, and they also have enough time to acquaint themselves with the given technology and to explore its possibilities. These conclusions are in line with the findings of Chaudron et al. (2018), which state that despite the various forms in which parents enter the ICT-related activities of their children, the children are mostly self-explorers and self-learners in the use of technology. Apart from imitating parents, children very often learn to use the digital technologies on their own using trial and error, which further supports the autonomy and self-confidence of children in ICT usage. The research results of Chaudron et al. (2018) thus suggest that the use of technology by children at early ages can have a significant influence not only on the development of their ICT competence, but also (and maybe even more) upon the development of their autonomy in ICT usage.

This study is primarily interested in the relationship between the age at which students start using a computer and their level of perceived ICT competence and autonomy at fifteen years of age. Some studies addressing ICT experience have considered the number of years for which the child or student has been using ICT (Hargittai, 2005; Hatlevik et al., 2018; van Deursen & van Dijk, 2011; van Deursen, van Dijk, & Peters, 2011). Previous research suggests that the extent of experience with ICT, i.e. the age at which children start to use ICT, could truly be a significant factor in the development of ICT competence and autonomy. Livingstone and Helsper (2007) focused specifically on the use of the internet, discovering that children and young people use the internet longer (in terms of the number of years) and more frequently take more opportunities to develop their internet literacy. Similarly, van Deursen et al. (2011) discovered that the number of years for which the internet is used contributes significantly to the development of internet skills.

2.3. ICT usage, ICT interest, and ICT in social interaction

The development of ICT competence and autonomy can be significantly affected by a number of other ICT-related factors. As shown in the study by Goldhammer et al. (2016), it is possible to distinguish behavioral factors, understood as manifest characteristics related to the use of ICT by students, from latent cognitive-motivational factors that are responsible for students' attempting activities that involve the use of ICT and then continuing with these or other ICT-related activities.

In the field of behavioral factors, the degree or frequency of ICT usage, which is the topic of a number of studies in relation to ICT competence, can be considered the most important (Alkan & Meinck, 2016; Fraillon et al., 2014; Hatlevik, Guðmundsdóttir, & Loi, 2015; Livingstone & Helsper, 2007; Rohatgi et al., 2016). To summarize the results: ICT usage is positively related to ICT competence. ICT usage can of course occur in various environments and contexts, either in school or out of school, and this can significantly alter the relationship to ICT competence (Hatlevik, Ottestad, et al., 2015). Many children start to use ICT at a pre-school age (Chaudron et al., 2018; Johnson, 2010; Marsh et al., 2017; O'Hara, 2011; Ólafsson et al., 2014), which makes it important to discern between ICT usage at home and in the school environment. Despite this differentiation, ICT usage remains a rather complex construct and a number of research projects therefore use other complementary differentiations as well. This study distinguishes between using ICT in a home environment for fun or leisure-time activities and using ICT as a learning tool or for learning purposes (Fraillon et al., 2014; Rohatgi et al., 2016; Verhoeven, Heerwegh, & De Wit, 2016). The use of ICT for educational purposes usually concerns the performance of school-related tasks or activities (typically homework, etc.).

This study focuses primarily on two cognitive-motivational factors. The first is ICT interest, which is conceptualized as a content-specific motivational disposition in relation to the self-determination theory (Ryan & Deci, 2000). It can be understood as an individual preferring (long-term) participation in activities related to ICT and its use (Goldhammer et al., 2016). This preference can stem from positive feelings connected to ICT usage as such and also from realizing the value or benefit of using specific technological tools to fulfil personal goals (Christoph et al., 2015; Goldhammer et al., 2016; Zylka et al., 2015). If there is interest in ICT, a strong positive correlation with ICT usage can be expected. Since ICT interest as a motivational factor concerns primarily intrinsic motivation and since the intrinsic motivation is connected to a higher degree of participation and higher quality of the learning process (Ryan & Deci, 2000), in students with a higher ICT interest, a more prominent development of ICT competence and autonomy can be expected as well (Christoph et al., 2015).

The second cognitive-motivational factor explored in this study is the degree to which ICT is a part of the everyday social life of students, i.e. how much ICT is a topic of their everyday social interactions. On the basis of the self-determination theory (Ryan & Deci, 2000), this factor is understood in terms of relatedness or belongingness to others. Specifically, this factor can be understood as a personal need to share experience, knowledge, activities, and a general interest in ICT with others, especially because ICT becomes a subject of interpersonal communication and interaction (Goldhammer et al., 2016). Similarly to ICT interest, a positive connection can be expected with the degree of ICT usage and also with the degree of ICT competence and autonomy. Social interaction is the context in which informal and non-institutionalized learning often takes place (Goldhammer et al., 2016), and for this reason the phenomenon can be expected to be similar to ICT-related knowledge and abilities (Christoph et al., 2015; Zylka et al., 2015). In addition, the ICT-related social interactions of students occur primarily among peers, so peer learning can play a role here (Vekiri, 2010; Verhoeven et al., 2016).

2.4. The present study

With regard to the theoretical bases and the previous research, we developed three hypotheses. Our presumption that an out-of-school environment plays the primary role in the development of ICT competence and autonomy is based on the fact that children use ICT more often outside of school (Eurydice, 2011; Wastiau et al., 2013). This presumption is also supported by several research articles emphasizing the role of the home environment in ICT competence (Fraillon et al., 2014; Hatlevik et al., 2015, 2018). Thus, we expect that school-related factors will not play a dominant role in students' perceived ICT competence and autonomy.

Hypothesis 1. Only a small part of the variance in students' perceived ICT competence and autonomy at the age of fifteen can be explained by school-related factors.

Next, we presume that there will be a negative relationship between the age at which children start using a computer and their perceived ICT competence and autonomy at a later age, i.e. the lower the age at which children start using computer, the higher their perceived ICT competence and autonomy. This presupposition is supported by several research papers focused on internet use (Livingstone & Helsper, 2007; van Deursen et al., 2011). At the same time, we take into consideration the research focused on the use of computers and generally digital technologies at a young age, in accordance with which the continuously expanding use of ICT by children of pre-school age can play an important role in the development of their ICT competence and autonomy (Chaudron et al., 2018; Johnson, 2010; Marsh et al., 2017; O'Hara, 2011; Ólafsson et al., 2014).

Hypothesis 2. The age at which children start using a computer has a significant and negative relationship with the degree of their perceived ICT competence and autonomy at the age of fifteen.

We presume that the age at which children start using digital technologies is related to other ICT-related variables that can then simultaneously affect the development of competence and autonomy in ICT usage. Specifically, we expect the children who started to use ICT at an earlier age to use ICT more often at a later age and to be more interested in ICT. Moreover, we believe that ICT will play a more important role in their everyday social interaction that will then project into their ICT competence and autonomy. The relationship between the age at first computer use and perceived ICT competence and autonomy shall therefore be mediated through the aforementioned ICT-related variables, as the conceptual model in Fig. 1 shows.

Hypothesis 3. Apart from the direct effect, the age at which children start to use a computer also has an indirect effect upon the degree of their perceived ICT competence and autonomy at the age of fifteen through the use of ICT in the home environment, interest in ICT, and the degree to which ICT is a part of their everyday social interaction.

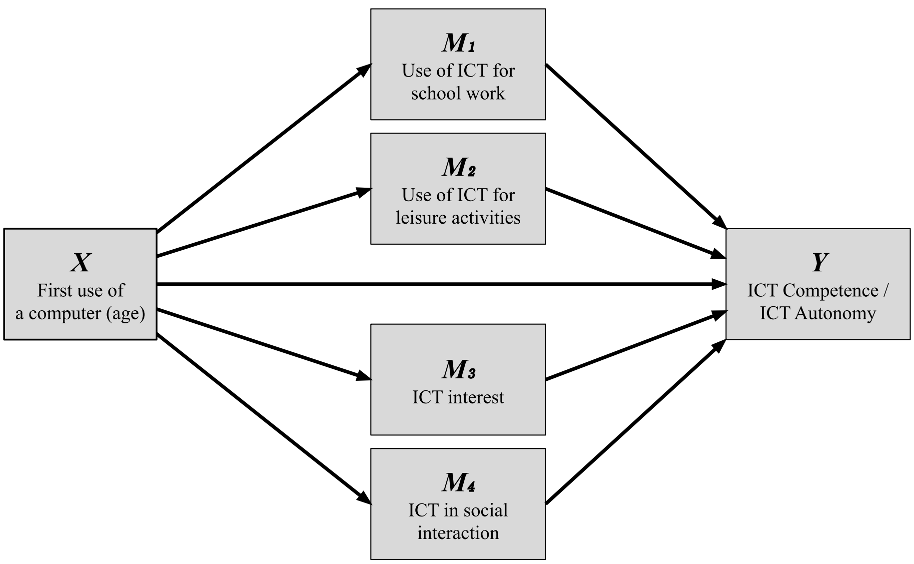

Fig. 1. A conceptual diagram of a parallel multiple mediator model with four different mediators.

3. Methods

3.1. Sample and procedure

Data analyzed in this study were provided by the PISA 2015 international assessment. A total of 73 world countries and regions participated in this assessment. From this assessment, we used data from complementary questionnaires focusing on the wider contexts of respondents, particularly from the ICT Familiarity Questionnaire. This questionnaire was an optional part of the assessment. It has been used in 30 of the OECD countries in total. For the purposes of this study, we focused only on OECD countries in Europe, thus giving us a sample of data from a total of 21 European countries.[2] The sample contains only answers from students who declared that they had at least some experience with using a personal computer. In total, the data contains information from 123,983 students from 5115 schools. More detailed information on the number of students and schools is available in Table 1. Comprehensive information on the data collection procedure and the ICT Familiarity Questionnaire content and its development can be found in the PISA 2015 technical report (OECD, 2017b).

3.2. Measures

3.2.1. Dependent variables

The dependent variables are the degree of students' perceived competence in ICT usage (COMPICT) and the degree of students' perceived autonomy related to ICT usage (AUTICT). Both variables are based on a total of five items that were a part of the question concerning experience with electronic media and devices. The students expressed a degree of agreement or disagreement with selected statements (such as: *I feel comfortable using digital devices that I am less familiar with* or *If I need new software, I install it by myself*) on a four-point Likert scale. Both variables were used in the PISA assessment for the first time in 2015 and they have been scaled using the item response theory (IRT). Average values and the standard deviations of both scales for individual countries are available in Table 1. For ICT competence, the reliability of the created index ranges from 0.82 to 0.88 (Cronbach's Alpha coefficients) in selected countries. For ICT autonomy, the reliability ranges from 0.81 to 0.91. Specific coefficients of individual countries are available in the PISA 2015 technical report (OECD, 2017b).

3.2.2. Independent variable

The independent variable originates in the question: “How old were you when you first used a computer?” (in the PISA 2015 dataset, this is denoted as IC003Q01TA), to which students responded by choosing one of the following five options: 1) *6 years old or younger*, 2) *7–9 years old*, 3) *10–12 years old*, 4) *13 years old or older*, or 5) *I had never used a computer until today*. The students who selected option 5 (i.e. had never used a computer before) were excluded from the analyses. Moreover, for the purposes of the analysis, and because the category *13 years old or older* included very few students in many countries, options 3 and 4 were combined into one category: *10 years old or older*.

The resulting independent variable used has three categories: 1) *6 years old or younger*, 2) *7–9 years old*, and 3) *10 years old or older*. The proportional representation of individual categories in the population of students from selected countries is available in Table 1. Within the performed analyses, “dummy coding” was used for this variable and the category *6 years old or younger* was used as a reference category.

3.2.3. Potential mediators

A total of four different variables were used as potential mediators in the modeling. The first two variables involve the degree of ICT usage by students outside of school; we distinguish between student use of ICT outside of school for schoolwork (HOMESCH) and student use of ICT outside of school for leisure activities (ENTUSE). Student ICT interest (INTICT) is the third variable, and the last potential mediator is the degree to which ICT is a part of students' daily social life (SOIAICT). All of these variables were scaled using IRT.

For the use of ICT in the home environment, the questions concerned the frequency of usage of electronic devices for selected activities. The cumulative index was created on the basis of a total of 12 items. Average values of the HOMESCH index range from −0.52 to 0.34 for individual countries and the reliability of the index ranges from 0.85 to 0.94 in selected countries. For the ICT usage index for leisure time activities (i.e. ENTUSE) the average values range from −0.13 to 0.22 in selected countries and the reliability of the index ranges from 0.74 to 0.85. For variables involving interest in ICT and ICT as a part of the everyday social life of students, the questionnaire measured the degree of agreement or disagreement with selected statements regarding experience with electronic media and devices (similarly to the competence and autonomy in ICT usage). Students then expressed their opinion in response to every statement on a four-point Likert scale. The average values of the INTICT index range from −0.26 to 0.38 in the analyzed countries; the index reliability then ranges from 0.74 to 0.82. In the SOIAICT index, average values range from −0.23 to 0.43; the reliability ranges from 0.8 to 0.9. Descriptive statistics and correlations of all used variables are available in the attached data files.

[2] Of the European OECD countries, Germany and Luxembourg have been excluded for not using a complete set of items from the ICT Familiarity Questionnaire used in this study, i.e. for the unsuitability of data for the analysis.

Table 1
Basic description of the sample, the independent variable, and the dependent variables.

Country code	$N_{Students}$	% of females	$N_{Schools}$	First use of a computer (%)			ICT Competence		ICT Autonomy	
				6 years old or younger	7–9 years old	10 years old or older	M	SD	M	SD
AUT	6714	49.7	261	19.5	43.9	36.5	-.08	1.07	.2	1.12
BEL	8652	49.8	268	23.5	44.4	32.2	.05	.96	.04	.93
CHE	5617	48.4	227	18.3	43.9	37.8	.05	1.03	.16	1.01
CZE	6532	5.4	332	32.2	49.7	18	-.09	.96	-.09	.94
DNK	6231	51.4	330	45	42.6	12.4	.26	.95	.12	.96
EST	5334	5.3	206	49.4	41.4	9.2	-.05	.95	-.01	.97
FIN	5597	49.1	162	47.9	44.4	7.7	-.08	.9	.15	.9
FRA	5625	51.6	251	23.4	44.1	32.4	.23	1.03	.32	.95
GBR	5203	48.4	245	42.3	43.8	13.9	.35	.93	.18	.97
GRC	5291	49.9	210	19.1	40.9	40	.06	.95	-.15	.94
HUN	5414	5.7	244	34.4	46.8	18.8	.07	.99	-.01	1
IRL	5607	49.6	167	27.8	47	25.2	.21	.9	.11	.93
ISL	3226	52.1	124	48.6	38.8	12.6	-.01	.93	.1	1.08
ITA	10744	5.8	463	21	47.2	31.8	-.02	.92	-.05	.92
LVA	4738	50	249	28.8	52	19.2	-.13	.9	-.01	.94
NLD	5157	5.6	181	37.4	48.6	14	-.03	.84	-.01	.85
POL	4414	49.6	169	38.9	48.8	12.2	.02	.94	.05	.93
PRT	6959	50	245	28.8	47	24.3	.39	.92	-.06	.97
SVK	5909	48.5	280	19.4	48	32.6	-.12	.96	-.29	.96
SVN	6024	46.5	300	32.1	49.1	18.8	.06	.96	-.14	.93
SWE	4995	51	201	49.8	39.6	10.6	.27	1.03	.18	1.1

Note. The meaning of the country codes is as follows (same for all tables): AUT (Austria), BEL (Belgium), CHE (Switzerland), CZE (Czech Republic), DNK (Denmark), EST (Estonia), FIN (Finland), FRA (France), GBR (United Kingdom of Great Britain and Northern Ireland), GRC (Greece), HUN (Hungary), IRL (Ireland), ISL (Iceland), ITA (Italy), LVA (Latvia), NLD (Netherlands), POL (Poland), PRT (Portugal), SVK (Slovakia), SVN (Slovenia), SWE (Sweden). In the United Kingdom, the questionnaire was only administered to a subset of students excluding Scotland.

3.2.4. Controlling variables

In all the analyses, gender and the index of economic, social, and cultural status (ESCS) were used as controlling variables. For student gender, we used effect coding, in which females were coded as 1 and males as -1. The construction of the ESCS index is rather complex in the PISA assessment. A detailed description of the index construction can be found in the PISA 2015 technical report (OECD, 2017b).

3.3. Data analysis

Multilevel modeling (Heck & Thomas, 2015; Hox, 2010; Snijders & Bosker, 2012) and mediation analysis (Hayes, 2018; MacKinnon, 2008) were used to answer the research question. The analysis itself was performed in the statistic environment R (R Core Team, 2018), in particular using the *BIFIEsurvey* package (BIFIE, 2018).

All the analyses were performed separately for every country that was included in the sample, and simultaneously separately for both the dependent variables analyzed (i.e. ICT competence and ICT autonomy). The analyses started with calculating the necessary descriptive statistics and correlations and continued with creating "null models" and a calculation of an intra-class correlation coefficients (ICC). Subsequently, all partial models necessary for the mediation analysis were calculated. The mediation analysis involved a parallel multiple mediator model with a multi-categorical independent variable, as the diagram in Fig. 2 suggests. The diagram does not show the relationships between controlling variables and the individual mediators and the relationships between controlling variables and the dependent variable, even though these relationships have been included in the calculated models. These relationships are denoted with the letters *f* or *g* in the attached data.

The results of the mediation analysis are reported in the form of relative total effects (c_1 and c_2), relative direct effects (c'_1 and c'_2) and relative indirect effects ($a_{11}b_1$, $a_{21}b_1$, $a_{12}b_2$ etc., see Fig. 2 and Tables 3–6). In connection with Hypothesis 3, concerning the indirect effect in the considered model, we tested the statistical significance of individual relative indirect effects using a Sobel test (Sobel, 1982).[3] As a measure of effect size, we use a variation of Cohen's f^2 (Aiken & West, 1991; Cohen, 1988)[4] for calculating effect

[3] A growing number of authors recommend avoiding the Sobel test and using the bootstrapping method instead (Hayes, 2018; MacKinnon, 2008; Preacher & Hayes, 2008). We completely agree that the bootstrapping method is preferable to the Sobel test, mainly because of the problematic assumption with the Sobel test of the normal distribution of *ab*. However, the bootstrapping method is computationally quite intensive, which could become an issue when analyzing data from international large-scale assessments (ILSAs) like PISA. In our case, the bootstrapping method would involve an extremely high computational time; therefore, we employ the Sobel test (similarly to other researchers working with data from ILSAs, e.g. Lee & Wu, 2013; Rohatgi et al., 2016).

[4] $f^2 = (R_2^2 + R_1^2) / (1 + R_2^2)$ where R_2^2 is the variance explained for a full model with the given effect and R_1^2 is the variance explained for a reduced model (i.e. without the given effect).

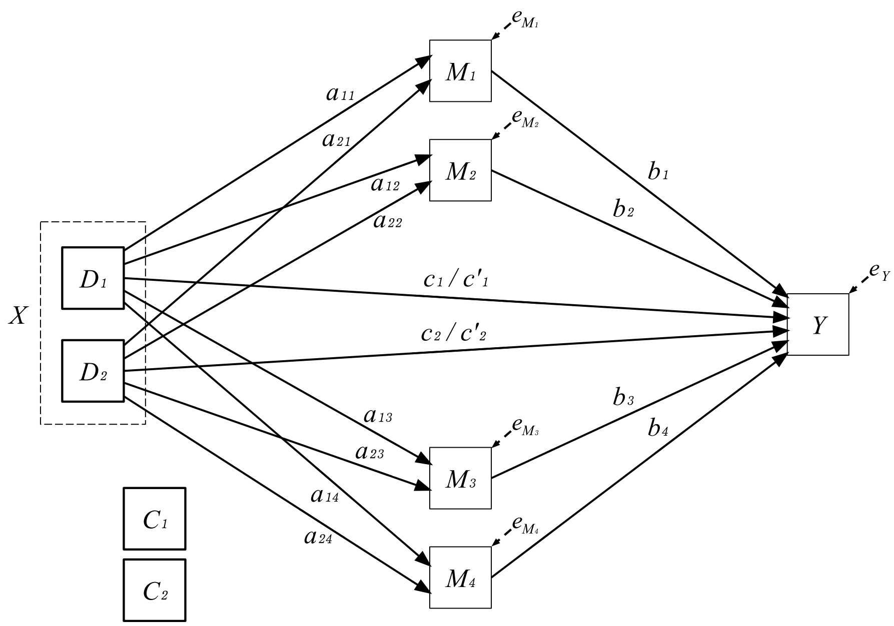

Fig. 2. A statistical diagram of the parallel multiple mediator model with a multi-categorical antecedent X (with two variables D representing the categories), four mediators M, two statistical controls C, and a consequent variable Y.

sizes of total and direct effects, which is appropriate for use in the context of multilevel modeling and PISA data (Lorah, 2018). In case of indirect effects, the partially standardized indirect effects and proportion mediated are used as effect size measures (Miočević, O'Rourke, MacKinnon, & Brown, 2018; Preacher & Kelley, 2011).

4. Results

4.1. Intra-class correlation coefficients (Hypothesis 1)

The first step in the set hypotheses testing was the creation of "null models". Two two-level random intercept models without any explanatory variables were created for every country analyzed, once with perceived ICT competence as a dependent variable and once with perceived ICT autonomy as a dependent variable. On the basis of these models, intra-class correlation coefficients (ICC)[5] were calculated; these allowed us to determine how much of the variance in perceived ICT competence and autonomy can be attributed to school-level differences and how much to student-level differences. The ICC values for individual countries are available in Table 2. Although in some countries the value of ICC is significantly different from zero, in all countries the value of ICC is lower than 0.05; in educational research this is usually considered to be a small intra-class correlation (Hox, 2010; Snijders & Bosker, 2012). Therefore, we can conclude that in all countries the differences between schools are relatively small both in perceived ICT competence and perceived ICT autonomy, meaning that only a very small part of the variance in perceived ICT competence (0.9% on average) and ICT autonomy (1.2% on average) can be explained by school-related factors.

4.2. Total effects (Hypothesis 2)

A model was created to test the second set hypothesis regarding the relationship between the age at which children start using a computer and the degree of their perceived ICT competence and ICT autonomy. The model only contained the age at the first use of a PC as an explanatory variable (*X*); gender (C_1) and ESCS (C_2) played the role of controlling variables. This model allowed us to estimate the total effect of the age at first PC use on perceived ICT competence and ICT autonomy. Since the explanatory variable has a categorical character and consists of a total of three categories, these categories were represented in the model using two dummy variables (D_1 and D_2); the category *6 years old or younger* served as a reference category. Therefore, the total effect of the multi-categorical variable *X* on the dependent variable *Y* is expressed through two relative total effects (c_1 and c_2). The specific relative total effects per individual countries for ICT competence and ICT autonomy are stated in Table 3 together with the f^2 effect size measure.

As the results in the table show, a negative relationship in both ICT competence and ICT autonomy was found in all the examined countries. This means that children who stated that they started using a PC at a later age (i.e. at 7 years of age and later), achieved a significantly lower level of ICT competence and ICT autonomy. Children who started to use a PC between 7 and 9 years of age

[5] $ICC = \sigma^2_{u0j} / (\sigma^2_{u0j} + \sigma^2_{rij})$ where σ^2_{u0j} is the between-school variance and σ^2_{rij} is the within-school variance (Snijders & Bosker, 2012).

Table 2
Intra-class correlation coefficients for competence and autonomy in using ICT.

Country code	$ICC_{Competence}$ (SE)	$ICC_{Autonomy}$ (SE)
AUT	.024 (.008)**	.034 (.009)**
BEL	.011 (.006)	.021 (.005)**
CHE	.033 (.013)*	.023 (.008)**
CZE	.015 (.005)**	.043 (.009)**
DNK	.006 (.005)	.003 (.004)
EST	< .000 (< .000)**	< .000 (< .000)**
FIN	.004 (.006)	.002 (.004)
FRA	< .000 (< .000)**	< .000 (< .000)**
GBR	.003 (.005)	.006 (.007)
GRC	< .000 (< .000)**	< .000 (< .000)**
HUN	< .000 (< .000)**	.005 (.007)
IRL	.012 (.005)*	.024 (.005)**
ISL	.007 (.009)	.004 (.01)
ITA	.004 (.006)	.011 (.009)
LVA	.001 (< .000)**	.001 (< .000)**
NLD	.001 (.001)	.001 (< .000)**
POL	.002 (.004)	.004 (.005)
PRT	.019 (.014)	.007 (.005)
SVK	.023 (.011)*	.029 (.008)**
SVN	.015 (.009)	.023 (.013)
SWE	.001 (< .000)**	< .000 (< .000)**

Note. * = $p < .05$, ** = $p < .01$.

Table 3
Relative total effects for ICT Competence and ICT Autonomy.

Country code	ICT Competence			ICT Autonomy		
	Relative total effects		Effect sizes	Relative total effects		Effect sizes
	c_1	c_2	f^2	c_1	c_2	f^2
AUT	-.28**	-.4**/**	.024	-.33**	-.39**/*	.023
BEL	-.24**	-.36**/**	.022	-.26**	-.36**/**	.024
CHE	-.26**	-.36**/**	.02	-.25**	-.39**/**	.024
CZE	-.23**	-.31**/*	.022	-.25**	-.34**/**	.029
DNK	-.16**	-.19**/	.01	-.19**	-.23**/	.015
EST	-.15**	-.31**/**	.015	-.14**	-.35**/**	.017
FIN	-.16**	-.19**/	.009	-.18**	-.25**/	.013
FRA	-.31**	-.42**/**	.025	-.27**	-.43**/**	.031
GBR	-.25**	-.37**/**	.032	-.24**	-.35**/**	.028
GRC	-.26**	-.43**/**	.031	-.29**	-.47**/**	.039
HUN	-.24**	-.39**/**	.024	-.27**	-.38**/*	.026
IRL	-.31**	-.41**/**	.033	-.31**	-.42**/**	.034
ISL	-.15**	-.22**/	.009	-.18**	-.22**/	.009
ITA	-.25**	-.38**/**	.048	-.22**	-.35**/**	.039
LVA	-.19**	-.34**/**	.021	-.27**	-.33**/	.024
NLD	-.2**	-.27**/*	.019	-.2**	-.25**/	.018
POL	-.23**	-.37**/**	.022	-.24**	-.4**/**	.026
PRT	-.29**	-.41**/**	.042	-.28**	-.42**/**	.04
SVK	-.21**	-.32**/**	.016	-.26**	-.38**/**	.023
SVN	-.31**	-.36**/	.035	-.28**	-.33**/	.032
SWE	-.19**	-.27**/	.012	-.24**	-.26**/	.015

Note. * = $p < .05$, ** = $p < .01$, the slash symbol is used to separate statistical significance with regard to the reference category (6 years old or younger) and with regard to the second category (7–9 years old).

achieved a level of ICT competence lower by −0.15 to −0.31 and a level of ICT autonomy lower by −0.14 to −0.33 in the individual countries. Children who used a computer for the first time after the age of 10 reached a level of ICT competence lower by −0.19 to −0.43 and a level of ICT autonomy lower by −0.22 to −0.47 compared to the reference category (i.e. 6 years old or younger). At the same time, in some countries there was not a significant difference between children who started using a PC between 7 and 9 years of age and children who started at the age of 10 or later. For both ICT competence and autonomy, this applies to Denmark, Finland, Iceland, Slovenia, and Sweden; for ICT autonomy, this also applies to Lithuania and Netherlands.

The effect sizes in individual countries vary between 0.009 and 0.048 (with a mean of 0.023) for ICT competence and between 0.009 and 0.040 (with a mean of 0.025) for ICT autonomy. This means that the age at which children start using a computer explains

Table 4
Relative direct effects for ICT Competence and ICT Autonomy.

Country code	ICT Competence			ICT Autonomy		
	Relative direct effects		Effect sizes	Relative direct effects		Effect sizes
	c_1	c_2	f^2	c_1	c_2	f^2
AUT	-.13**	-.18$^{**/}$	.005	-.2**	-.21$^{**/}$	.007
BEL	-.13**	-.17$^{**/*}$	.007	-.14**	-.18$^{**/}$	.008
CHE	-.14**	-.18$^{**/}$	.007	-.14**	-.23$^{**/**}$	.01
CZE	-.07**	-.09$^{**/}$	.003	-.1**	-.16$^{**/*}$	.008
DNK	-.06*	-.04$^{/}$	.001	-.1**	-.09$^{*/}$	.004
EST	-.05*	-.12$^{**/}$	.003	-.05*	-.18$^{**/**}$	.005
FIN	-.06**	-.03$^{/}$	.001	-.09**	-.12$^{**/}$	.004
FRA	-.16**	-.18$^{**/}$	.007	-.14**	-.21$^{**/**}$	.011
GBR	-.14**	-.18$^{**/}$	.01	-.13**	-.17$^{**/}$	.008
GRC	-.17**	-.21$^{**/}$	.01	-.2**	-.25$^{**/}$	.015
HUN	-.1**	-.13$^{**/}$	.004	-.13**	-.15$^{**/}$	.006
IRL	-.17**	-.19$^{**/}$	.011	-.18**	-.22$^{**/}$	.013
ISL	-.04	-.07$^{/}$	.001	-.07	-.07$^{/}$	.001
ITA	-.12**	-.19$^{**/**}$	.009	-.09**	-.17$^{**/**}$	.008
LVA	-.08*	-.14$^{**/}$	.005	-.16**	-.15$^{**/}$	.009
NLD	-.07**	-.08$^{*/}$	.003	-.08**	-.07$^{*/}$	.003
POL	-.09**	-.11$^{**/}$	.003	-.09**	-.16$^{**/*}$	.006
PRT	-.15**	-.2$^{**/}$	.012	-.16**	-.24$^{**/**}$	.015
SVK	-.07*	-.1$^{**/}$	.002	-.1**	-.16$^{**/*}$	.007
SVN	-.17**	-.16$^{**/}$	.011	-.16**	-.16$^{**/}$	.009
SWE	-.05	-.11$^{*/}$	.001	-.1**	-.09$^{/}$	.002

Note. $^{*} = p < .05$, $^{**} = p < .01$, the slash symbol is used to separate statistical significance with regard to the reference category (6 years old or younger) and with regard to the second category (7–9 years old).

about 1%–5% of the variance in students' perceived ICT competence and autonomy at the age of fifteen (relative to unexplained variance). An f^2 around 0.02 is usually considered to be a small effect size (Cohen, 1988; Lorah, 2018); however, the size of the effect should always be interpreted in context. In the present study, we were interested in the effect of the age at which children started using a computer on their perceived ICT competence and autonomy at the age of fifteen. In the context of the present study, it cannot be expected that the effect of age at first computer use on their perceived ICT competence and autonomy at the age of fifteen would be large, especially not in comparison with other ICT-related variables like the student ICT interest and the frequency of student use of ICT at the age of fifteen. Therefore, we believe that even the effect of a few percent of explained variance could be actually interpreted as relatively big in this context.

4.3. Direct and indirect effects (Hypothesis 3)

The third set hypothesis concerned the possible indirect effect of the age at first PC use on perceived ICT competence and autonomy through other ICT-related variables. A parallel multiple mediator model, in which four variables functioned as mediators, was created for testing. This made it possible to distinguish the direct and indirect effect of the age at first PC use upon perceived ICT competence and autonomy through individual mediators. With regard to the use of the multi-categorical independent variable, two relative direct effects (c'_1 and c'_2) are reported for every dependent variable (see Table 4). In the same manner, two relative indirect effects are reported for every used mediator. The relative indirect effects for ICT competence are stated in Table 5; the relative indirect effects for ICT autonomy are stated in Table 6. Gender and ESCS again served as controlling variables in all the models.

The results in Table 5 show that the degree of use of ICT in a home environment for school purposes (HOMESCH) was not a significant mediator for ICT competence in any of the countries analyzed. In contrast, other analyzed mediators appeared to be significant in almost all countries. The only exception was Sweden and the degree of ICT usage for leisure time activities in a home environment (ENTUSE), which does not appear to significantly mediate the relationship between age and perceived ICT competence. Most countries show a partial mediation, since there is still a significant direct effect of the age at first PC use on ICT competence (see Table 4). Denmark, Finland, Sweden, and especially Iceland represent a certain exception. Table 5 also presents an effect size measure of the indirect effects.[6] This effect size can be understood as the proportion of the total effect that is due to the indirect effect. As Table 5 clearly shows, proportion mediated ranges from 0.38 to 0.75 in ICT competence (mean = 0.57), which could be viewed as a relatively high indirect effect.

[6] We estimated the partially standardized indirect effects as a recommended effect size measure (see Miočević et al., 2018) as well, but we refrained from reporting this effect size in the table due to limited space. Moreover, in most of the cases, the partially standardized indirect effect is actually the same as the raw coefficients presented in the table (in the rest of the cases it is 0.01 higher or lower), because of the character of the dependent variables (i.e. *M* close to 0 and *SD* close to 1).

Table 5
Relative indirect effects and proportion mediated for ICT competence.

Country code	M_1(HOMESCH)		M_2(ENTUSE)		M_3(INTICT)		M_4(SOIAICT)		Proportion mediated	
	$a_{11}b_1$	$a_{21}b_1$	$a_{12}b_2$	$a_{22}b_2$	$a_{13}b_3$	$a_{23}b_3$	$a_{14}b_4$	$a_{24}b_4$	a_1b	a_2b
AUT	< .00	< .00	-.02**	-.02**	-.06**	-.11**	-.06**	-.08**	.5	.54
BEL	< .00	< .00	-.02**	-.04**	-.07**	-.12**	-.03**	-.05**	.49	.55
CHE	< .00	< .00	-.02**	-.03**	-.08**	-.12**	-.03*	-.03**	.47	.49
CZE	< .00	< .00	-.01**	-.02**	-.08**	-.13**	-.06**	-.06**	.68	.69
DNK	< .00	< .00	-.02**	-.03**	-.06**	-.1**	-.02*	-.03**	.62	.81
EST	< .00	< .00	-.01**	-.01*	-.04**	-.11**	-.04**	-.07**	.65	.62
FIN	< .00	< .00	-.01**	-.02**	-.06**	-.09**	-.03**	-.04*	.64	.81
FRA	< .00	< .00	-.02**	-.03**	-.06**	-.13**	-.06**	-.07**	.48	.57
GBR	< .00	< .00	-.01*	-.02**	-.07**	-.14**	-.03**	-.03**	.43	.51
GRC	< .00	< .00	-.02**	-.03**	-.05**	-.11**	-.04**	-.1**	.38	.53
HUN	< .00	< .00	-.02**	-.03**	-.09**	-.17**	-.04**	-.06**	.61	.67
IRL	< .00	< .00	-.02**	-.03**	-.07**	-.12**	-.04**	-.06**	.45	.53
ISL	< .00	< .00	-.02**	-.02**	-.06**	-.1**	-.02*	-.03*	.72	.68
ITA	< .00	< .00	-.02**	-.03**	-.08**	-.12**	-.04**	-.05**	.55	.51
LVA	.01	.01	-.02**	-.03**	-.05**	-.11**	-.05**	-.06**	.58	.58
NLD	< .00	< .00	-.02**	-.03**	-.08**	-.13**	-.03**	-.04**	.65	.71
POL	< .00	< .00	-.02**	-.03**	-.06**	-.11**	-.07**	-.11**	.63	.68
PRT	< .00	< .00	-.02**	-.03**	-.07**	-.12**	-.05**	-.07**	.48	.52
SVK	< .00	< .00	-.02**	-.02**	-.06**	-.12**	-.07**	-.08**	.67	.7
SVN	< .00	< .00	-.02**	-.04**	-.08**	-.11**	-.04**	-.05**	.46	.55
SWE	< .00	< .00	-.01	0	-.07**	-.1**	-.07**	-.06**	.75	.61

Note. $^{*} = p < .05$, $^{**} = p < .01$, *Proportion mediated* is an effect size measure assessing the relative magnitude of the indirect effect. Because of the use of the multi-categorical independent variable X, two proportions mediated (a_1b and a_2b) are reported. Proportions mediated is calculated as follows: $(a_{11}b_1 + a_{12}b_2 + a_{13}b_3 + a_{14}b_4)/(a_{11}b_1 + a_{12}b_2 + a_{13}b_3 + a_{14}b_4 + c'_1)$ and $(a_{21}b_1 + a_{22}b_2 + a_{23}b_3 + a_{24}b_4)/(a_{21}b_1 + a_{22}b_2 + a_{23}b_3 + a_{24}b_4 + c'_2)$.

Table 6
Relative indirect effects and proportion mediated for ICT autonomy.

Country code	M_1(HOMESCH)		M_2(ENTUSE)		M_3(INTICT)		M_4(SOIAICT)		Proportion mediated	
	$a_{11}b_1$	$a_{21}b_1$	$a_{12}b_2$	$a_{22}b_2$	$a_{13}b_3$	$a_{23}b_3$	$a_{14}b_4$	$a_{24}b_4$	a_1b	a_2b
AUT	< .00	< .00	-.02**	-.03**	-.05**	-.09**	-.06**	-.08**	.39	.5
BEL	.01**	.01**	-.03**	-.04**	-.05**	-.09**	-.04**	-.06**	.43	.51
CHE	< .00	< .00	-.02**	-.03**	-.05**	-.08**	-.03*	-.03**	.42	.39
CZE	< .00	< .00	-.02**	-.02**	-.06**	-.1**	-.07**	-.07**	.58	.54
DNK	< .00	< .00	-.02**	-.04**	-.04**	-.07**	-.03*	-.04**	.47	.62
EST	< .00	< .00	-.01**	-.02**	-.03**	-.09**	-.04**	-.07**	.63	.49
FIN	< .00	-.01	-.02**	-.02**	-.05**	-.07**	-.03**	-.03*	.49	.53
FRA	< .00	< .00	-.03**	-.04**	-.05**	-.11**	-.05**	-.06**	.49	.5
GBR	< .00	< .00	-.02**	-.04**	-.05**	-.11**	-.04**	-.05**	.46	.53
GRC	< .00	< .00	-.02**	-.04**	-.03**	-.06**	-.05**	-.11**	.33	.47
HUN	< .00	< .00	-.03**	-.05**	-.06**	-.11**	-.06**	-.08**	.52	.62
IRL	< .00	< .00	-.02**	-.04**	-.06**	-.1**	-.05**	-.06**	.42	.47
ISL	< .00	< .00	-.02**	-.02*	-.05**	-.07**	-.03*	-.04*	.58	.66
ITA	< .00	< .00	-.02**	-.03**	-.06**	-.09**	-.05**	-.06**	.6	.51
LVA	.01*	.01	-.02**	-.03**	-.04**	-.1**	-.06**	-.07**	.42	.57
NLD	< .00	< .00	-.03**	-.04**	-.06**	-.09**	-.04**	-.05**	.62	.73
POL	.01	< .00	-.02**	-.04**	-.05**	-.08**	-.08**	-.12**	.6	.6
PRT	< .00	< .00	-.02**	-.04**	-.03**	-.05**	-.07**	-.09**	.44	.44
SVK	< .00	< .00	-.03**	-.04**	-.04**	-.08**	-.09**	-.11**	.61	.6
SVN	< .00	< .00	-.03**	-.05**	-.05**	-.06**	-.05**	-.06**	.43	.53
SWE	< .00	< .00	-.02**	-.01*	-.05**	-.06**	-.08**	-.07**	.6	.62

Note. $^{*} = p < .05$, $^{**} = p < .01$, *Proportion mediated* is an effect size measure assessing the relative magnitude of the indirect effect. Because of the use of the multi-categorical independent variable X, two proportions mediated (a_1b and a_2b) are reported. Proportions mediated is calculated as follows: $(a_{11}b_1 + a_{12}b_2 + a_{13}b_3 + a_{14}b_4)/(a_{11}b_1 + a_{12}b_2 + a_{13}b_3 + a_{14}b_4 + c'_1)$ and $(a_{21}b_1 + a_{22}b_2 + a_{23}b_3 + a_{24}b_4)/(a_{21}b_1 + a_{22}b_2 + a_{23}b_3 + a_{24}b_4 + c'_2)$.

At the same time, Table 4 shows that for relative direct effects, in most countries there is not a statistically significant difference between children who start using their PC between 7 and 9 years of age and children who start at the age of 10 or later. That suggests that the significant difference lies primarily in whether children acquire experience with a PC at or before 6 years of age or later. For children who acquire their first experience with a PC at a later age, it is less important whether they acquire it between 7 and 9 years of age or at 10 years of age or later. As for the effect sizes of relative direct effects, these are smaller than in the relative total effects. This is assumed to be a result of shared variance between the age at first PC use variable and the other ICT-related variables.

The results for ICT autonomy are very similar to the results for ICT competence. However, certain differences can be perceived. Above all, the strength of the influence of individual mediators varies. In ICT competence, interest in ICT played a primary role; the effect of ICT in social interaction (SOIAICT) and the use of ICT in leisure time (ENTUSE) was smaller. In contrast, for ICT autonomy, the interest in ICT is not as dominant, and in a number of countries the degree to which ICT is a part of the everyday social interaction of students has the same influence as interest in ICT. Likewise, the role of ICT usage in leisure time (ENTUSE) is more prominent in ICT autonomy than in ICT competence. In one case (Belgium), the variable concerning ICT usage in a home environment for school purposes (HOMESCH) proved to be a significant mediator in connection with ICT autonomy, but in comparison to other mediators, it played only a minor role.

5. Discussion and conclusion

The goal of this study was to investigate the relationship between the age at which children start using a computer and their perceived competence and autonomy in ICT usage at the age of fifteen. We were also interested whether and by how much this relationship is affected by the level of ICT usage by students in a home environment (both for leisure time activities and for school purposes), student interest in ICT, and the degree to which ICT is a part of students' everyday social interactions. In the following part of the text, we will first discuss our findings in connection with individual set hypotheses and then focus on the main limitations of this study.

The first hypothesis was focused on the degree to which the differences in perceived ICT competence and autonomy can be explained by school-related factors. The calculated intra-class correlation coefficients show that the school level (i.e. school-related factors) can explain only a small percentage of variability in perceived ICT competence (up to 3.3%) and ICT autonomy (up to 4.3%). The degree of perceived ICT competence and ICT autonomy is thus by all accounts affected primarily by factors other than school-related factors. These acquired results follow the findings of Aesaert, van Braak, et al. (2015) and Aesaert, van Nijlen, et al. (2015), who state that almost the entire range of ICT competence is situated at the student level and that the differences on higher levels (class level and school level) are small and insignificant. Similarly in the research of Hatlevik et al. (2018), who used data from the ICILS 2013 study and focused on ICT self-efficacy, the range in ICT self-efficacy explicable by the school level did not exceed 6% in European countries.

There are several possible explanations. First, it is possible that ICT is simply not used in schools frequently or intensively enough to manifest itself in the development of ICT competence and the autonomy of students (Aesaert et al., 2015). Second, it is possible that apart from the degree of ICT usage itself, the character of activities in which ICT is used plays an important role in the development of ICT competence and autonomy. In this case, what is crucial is that a home environment provides a safe place in which children and students can experiment and use ICT on a trial-and-error basis without the fear of possible bad grades. These conditions are suitable for exploring the options and various ways of using ICT, which can have an important influence upon the development of ICT competence and autonomy in ICT usage (Chaudron et al., 2018; Murphy & Beggs, 2003). However, we are convinced that the role of school in the development of ICT competence and autonomy of students cannot be completely overlooked. The research performed suggests that in this respect, school can play an absolutely fundamental role, especially in students from families with low socio-economic status (Vekiri, 2010).

The second hypothesis was focused directly on the relationship between the age at which children start using a PC and their perceived ICT competence and autonomy at a later age. In this case, we expected a negative relationship, i.e. the later the children start using a computer, the lower their level of ICT competence and ICT autonomy at the age of fifteen. This hypothesis was confirmed in almost all the countries examined, even when controlling for student gender and socio-economic status. Subsequently it was shown that, in many countries, there is no significant difference between students who started using a computer between seven and nine years of age and the students who first used a computer at the age of ten or later. These results suggest that rather than a linear relationship, this is a situation in which the pre-school period (i.e. until seven years of age) is a “critical” period and that the children's experience with digital technologies acquired in this particular period have a more important effect on the subsequent development of their ICT competence and autonomy than experience acquired later (comp. Chaudron et al., 2018). Similarly to Hatlevik et al. (2018), who achieved an analogous result in connection with ICT self-efficacy, we have to point out that this study used a rather nuanced marker for the age at first computer use (i.e. only three categories).

The last hypothesis concerned the effect of other ICT-related variables as mediators of the relationship between the age at first computer use and the degree of ICT competence and autonomy in students at the age of fifteen. The results show that the set hypothesis was confirmed in only three of the mediators considered. The variables of use of ICT in a home environment for leisure time, interest in ICT, and ICT in social interactions proved to be important mediators in almost all countries, both in relation to ICT competence and in relation to ICT autonomy. On the other hand, the use of ICT in a home environment for school purposes did not turn out to be an important mediator in almost any country (neither in ICT competence nor ICT autonomy). This further supports our finding that school factors explain very few differences in perceived ICT competence and autonomy. It also suggests that even if students use ICT for school purposes in home environments, these are not activities or manners of use that would develop their competence or autonomy in ICT usage.

Another important finding is the fact that even though the same mediators are important both in ICT competence and ICT autonomy, they differ in the degree to which they are connected to ICT competence or ICT autonomy. This suggests that individual factors participate in the development of ICT competence and ICT autonomy in a different manner. While the development of ICT competence is probably primarily connected to interest in ICT (even though other factors also play an important role), the degree to which ICT is a part of everyday social interaction is probably similarly important for the development of ICT autonomy.

Our findings regarding interest in ICT and ICT in social interaction are in partial compliance with other research conducted in this context. ICT in social interaction was also investigated by Alkan and Meinck (2016), who discovered an important positive relationship between ICT usage for social communication (for example, instant messaging, social network use, posting comments to blogs, etc.) and the results of students in CIL tests. Christoph et al. (2015) found a significant positive connection between ICT-related social engagement and theoretical computer knowledge and at the same time between interest in ICT (i.e. computers) and the level of basic computer skills.

5.1. Limitations

This study has certain limitations, which also suggest options for further research. The main limitation of the study is that in the model considered and calculations made, we worked with the degree of perceived ICT competence, which can only be considered an indirect measure of real skills and abilities concerning ICT usage by students. Although much research works with indirect measures, many researchers also warn of serious limitations. For example, the ICILS 2013 study determined an average correlation of only 0.32 between ICT self-efficacy in basic ICT skills and the results of students in CIL test across the countries included. For ICT self-efficacy in advanced ICT skills, this value was only 0.04 (Fraillon et al., 2014), which can be considered a very weak connection. Rohatgi et al. (2016) even found a negative connection with the results in CIL tests for ICT self-efficacy in advanced ICT skills.

In addition, the results of some research show that the accuracy of ICT self-efficacy in terms of predicting the real ICT skills of students can function differently in different groups of students. For example, in connection with ICT self-efficacy, some research identifies differences involving gender. Boys tend to overestimate their skills; girls underestimate theirs (Fraillon et al., 2014; Hargittai & Shafer, 2006). In accordance with Aesaert et al. (2017), students with a high degree of ICT competence evaluate their skills rather accurately; students with low ICT competence overestimate their skills. This limitation may be resolved by using the anchoring vignette method, as Vonkova and Hrabak (2015) propose, or by verifying our reported results using a method for directly measuring ICT competence.

Lastly, the use of two-level modeling could be considered as a kind of limitation. PISA includes country-level data; therefore three-level modeling could be employed using PISA data, as shown for example by Hu, Gong, Lai, and Leung (2018). It would then be possible to differentiate between student-level factors, school-level factors, and country-level factors instead of only between school-related factors and student-related (i.e. student-level) factors as we do in the present study.

Declaration of interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.compedu.2019.103614.

References

Aesaert, K., & van Braak, J. (2015). Gender and socioeconomic related differences in performance based ICT competences. *Computers & Education, 84*, 8–25. https://doi.org/10.1016/j.compedu.2014.12.017.

Aesaert, K., van Braak, J., van Nijlen, D., & Vanderlinde, R. (2015). Primary school pupils' ICT competences: Extensive model and scale development. *Computers & Education, 81*, 326–344. https://doi.org/10.1016/j.compedu.2014.10.021.

Aesaert, K., van Nijlen, D., Vanderlinde, R., Tondeur, J., Devlieger, I., & van Braak, J. (2015). The contribution of pupil, classroom and school level characteristics to primary school students' ICT competences: A performance-based approach. *Computers & Education, 87*, 55–69. https://doi.org/10.1016/j.compedu.2015.03.014.

Aesaert, K., Voogt, J., Kuiper, E., & van Braak, J. (2017). Accuracy and bias of ICT self-efficacy: An empirical study into students' over- and underestimation of their ICT competences. *Computers in Human Behavior, 75*, 92–102. https://doi.org/10.1016/j.chb.2017.05.010.

Aiken, L. S., & West, S. G. (1991). *Multiple regression: Testing and interpreting interactions.* Thousand Oaks: Sage Publications.

Alkan, M., & Meinck, S. (2016). The relationship between students' use of ICT for social communication and their computer and information literacy. *Large-Scale Assessments in Education, 4*, 1–17. https://doi.org/10.1186/s40536-016-0029-z.

Arnseth, H. C., Erstad, O., Juhaňák, L., & Zounek, J. (2016). Pedagogika a nové výzvy výzkumu ICT: Role digitálních technologií v každodenním životě a učení mládeže [Pedagogy and new challenges in ICT research: On the role of digital technologies in everyday life and youth learning]. *Studia Paedagogica, 21*, 87–110. https://doi.org/10.5817/SP2016-1-5.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory* (1st ed.). Englewood Cliffs: Prentice-Hall.

Bandura, A. (1997). *Self-efficacy: The exercise of control* (1st ed.). New York: W. H. Freeman and Company.

BIFIEsurvey, B. I. F. I. E. (2018). *Tools for survey statistics in educational assessment.* https://CRAN.R-project.org/package=BIFIEsurvey.

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., et al. (2012). Defining twenty-first century skills. In P. Griffin, B. McGaw, & E. Care (Eds.). *Assessment and teaching of 21st century skills* (pp. 17–66). Dordrecht: Springer Netherlands.

Byrne, B. M. (1996). Academic self-concept: Its structure, measurement, and relation to academic achievement. In B. A. Bracken (Ed.). *Handbook of self-concept: Developmental, social, and clinical considerations* (pp. 287–316). New York: Wiley.

Calvani, A., Fini, A., Ranieri, M., & Picci, P. (2012). Are young generations in secondary school digitally competent? A study on Italian teenagers. *Computers &*

Education, 58, 797–807. https://doi.org/10.1016/j.compedu.2011.10.004.
Chaudron, S. (2015). *Young children (0–8) and digital technology: A qualitative exploratory study across seven countries.* Luxembourg: Publications Office of the European Union.
Chaudron, S., Di Gioia, R., & Gemo, M. (2018). *Young children (0-8) and digital technology: A qualitative study across Europe.* Luxembourg: Publications Office of the European Union.
Christoph, G., Goldhammer, F., Zylka, J., & Hartig, J. (2015). Adolescents' computer performance: The role of self-concept and motivational aspects. *Computers & Education, 81*, 1–12. https://doi.org/10.1016/j.compedu.2014.09.004.
Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). New York: Lawrence Erlbaum Associates.
Coiro, J., Knobel, M., Lankshear, C., & Leu, D. J. (Eds.). (2008). *Handbook of research on new literacies*(1st ed.). New York: Lawrence Erlbaum Associates.
Deci, E. L., & Ryan, R. M. (2000). The “what” and “why” of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11*, 227–268. https://doi.org/10.1207/S15327965PLI1104_01.
van Deursen, A. J. A. M., & van Dijk, J. A. G. M. (2011). Internet skills and the digital divide. *New Media & Society, 13*, 893–911. https://doi.org/10.1177/1461444810386774.
van Deursen, A. J. A. M., van Dijk, J. A. G. M., & Peters, O. (2011). Rethinking Internet skills: The contribution of gender, age, education, internet experience, and hours online to medium- and content-related internet skills. *Poetics, 39*, 125–144. https://doi.org/10.1016/j.poetic.2011.02.001.
Erstad, O. (2008). Changing assessment practice and the role of it. In J. Voogt, & G. Knezek (Eds.). *International handbook of information technology in primary and secondary education* (pp. 181–194). New York: Springer.
Erstad, O. (2010). Educating the digital generation: Exploring media literacy for the 21st century. *Nordic Journal of Digital Literacy, 5*, 56–71.
Erstad, O. (2011). Weaving the context of digital literacy. In S. R. Ludvigsen, A. Lund, I. Rasmussen, & R. Säljö (Eds.). *Learning across sites: New tools, infrastructures and practices* (pp. 295–310). Cambridge: Cambridge University PRess.
Erstad, O. (2012). The learning lives of digital youth—beyond the formal and informal. *Oxford Review of Education, 38*, 25–43. https://doi.org/10.1080/03054985.2011.577940.
European Commission. (2007). *Key competences for lifelong learning—a European reference framework.* Luxembourg: Office for Official Publications of the European Communities.
Eurydice (2011). *Key data on learning and innovation through ICT at school in Europe 2011. Brussels: Education.* Audiovisual and Culture Executive Agency.
Ferrari, A. (2012). *Digital competence in practice: An analysis of frameworks.* Luxembourg: Publications Office of the European Union.
Fraillon, J., Ainley, J., Schulz, W., Friedman, T., & Gebhardt, E. (2014). *Preparing for life in a digital age: The IEA international computer and information literacy study international report*Cham: Springer International Publishing.
Goldhammer, F., Gniewosz, G., & Zylka, J. (2016). ICT engagement in learning environments. In S. Kuger, E. Klieme, N. Jude, & D. Kaplan (Eds.). *Assessing contexts of learning: An international perspective* (pp. 331–351). Cham: Springer International Publishing.
Griffin, P., McGaw, B., & Care, E. (Eds.). (2012). *Assessment and teaching of 21st century skills.* Dordrecht: Springer Netherlands.
Hargittai, E. (2005). Survey measures of web-oriented digital literacy. *Social Science Computer Review, 23*, 371–379. https://doi.org/10.1177/0894439305275911.
Hargittai, E., & Shafer, S. (2006). Differences in actual and perceived online skills: The role of gender. *Social Science Quarterly, 87*, 432–448. https://doi.org/10.1111/j.1540-6237.2006.00389.x.
Hatlevik, O. E., & Christophersen, K.-A. (2013). Digital competence at the beginning of upper secondary school: Identifying factors explaining digital inclusion. *Computers & Education, 63*, 240–247. https://doi.org/10.1016/j.compedu.2012.11.015.
Hatlevik, O. E., Guðmundsdóttir, G. B., & Loi, M. (2015a). Digital diversity among upper secondary students: A multilevel analysis of the relationship between cultural capital, self-efficacy, strategic use of information and digital competence. *Computers & Education, 81*, 345–353. https://doi.org/10.1016/j.compedu.2014.10.019.
Hatlevik, O. E., Ottestad, G., & Throndsen, I. (2015b). Predictors of digital competence in 7th grade: A multilevel analysis. *Journal of Computer Assisted Learning, 31*, 220–231. https://doi.org/10.1111/jcal.12065.
Hatlevik, O. E., Throndsen, I., Loi, M., & Guðmundsdóttir, G. B. (2018). Students' ICT self-efficacy and computer and information literacy: Determinants and relationships. *Computers & Education, 118*, 107–119. https://doi.org/10.1016/j.compedu.2017.11.011.
Hayes, A. F. (2018). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach* (2nd ed.). New York: The Guilford Press.
Heck, R. H., & Thomas, S. L. (2015). *An introduction to multilevel modeling techniques: MLM and SEM approaches using Mplus* (3rd ed.). New York: Routledge/Taylor & Francis Group.
Holloway, D., Green, L., & Livingstone, S. (2013). *Zero to eight: Young children and their internet use.* London: EU Kids Online. Retrieved January 15, 2019 from http://eprints.lse.ac.uk/52630/1/Zero_to_eight.pdf.
Hox, J. J. (2010). *Multilevel analysis: Techniques and applications* (2nd ed.). New York: Routledge/Taylor & Francis Group.
Hu, X., Gong, Y., Lai, C., & Leung, F. K. S. (2018). The relationship between ICT and student literacy in mathematics, reading, and science across 44 countries: A multilevel analysis. *Computers & Education, 125*, 1–13. https://doi.org/10.1016/j.compedu.2018.05.021.
Johnson, G. M. (2010). Internet use and child development: The techno-microsystem. *Australian Journal of Educational and Developmental Psychology, 10*, 32–43.
Katz, I. R., & Macklin-Smith, A. (2007). Information and communication technology (ICT) literacy: Integration and assessment in higher education. *Systemics, Cybernetics and Informatics, 5*, 50–55.
Knobel, M., & Lankshear, C. (2014). Studying new literacies. *Journal of Adolescent & Adult Literacy, 58*, 97–101. https://doi.org/10.1002/jaal.314.
Kuger, S., Klieme, E., Jude, N., & Kaplan, D. (Eds.). (2016). *Assessing contexts of learning: An international perspective.* Springer International Publishing.
Lankshear, C., & Knobel, M. (Eds.). (2008). *Digital literacies: Concepts, policies and practices (New literacies and digital epistemologies)*(1st.). New York: Peter Lang Inc., International Academic Publishers.
Lee, Y.-H., & Wu, J.-Y. (2013). The indirect effects of online social entertainment and information seeking activities on reading literacy. *Computers & Education, 67*, 168–177. https://doi.org/10.1016/j.compedu.2013.03.001.
Litt, E. (2013). *Measuring users' internet skills: A review of past assessments and a look toward the future. 15*, New Media & Society612–630. https://doi.org/10.1177/1461444813475424.
Livingstone, S., & Helsper, E. (2007). *Gradations in digital inclusion: Children, young people and the digital divide*, *Vol. 9*, New Media & Society671–696. https://doi.org/10.1177/1461444807080335.
Lorah, J. (2018). Effect size measures for multilevel models: Definition, interpretation, and TIMSS example. *Large-Scale Assessments in Education, 6*, 1–11. https://doi.org/10.1186/s40536-018-0061-2.
MacKinnon, D. P. (2008). *Introduction to statistical mediation analysis* (1st ed.). New York: Routledge.
Marsh, J., Hannon, P., Lewis, M., & Ritchie, L. (2017). Young children's initiation into family literacy practices in the digital age. *Journal of Early Childhood Research, 15*, 47–60. https://doi.org/10.1177/1476718X15582095.
Miočević, M., O'Rourke, H. P., MacKinnon, D. P., & Brown, H. C. (2018). Statistical properties of four effect-size measures for mediation models. *Behavior Research Methods, 50*, 285–301. https://doi.org/10.3758/s13428-017-0870-1.
Murphy, C., & Beggs, J. (2003). Primary pupils' and teachers' use of computers at home and school. *British Journal of Educational Technology, 34*, 79–83. https://doi.org/10.1111/1467-8535.d01-9.
OECD. (2017). *PISA 2015 results (Volume III): Students' well-being.* Paris: OECD Publishing.
OECD. (2017). *PISA 2015 Technical report*Paris: OECD Publishing.
Ólafsson, K., Livingstone, S., & Haddon, L. (2014). *Children's use of online technologies in Europe: A review of the European evidence base (revised edition).* London, UK: EU Kids Online. http://eprints.lse.ac.uk/60221/.
O'Hara, M. (2011). Young children's ICT experiences in the home: Some parental perspectives. *Journal of Early Childhood Research, 9*, 220–231. https://doi.org/10.1177/1476718X10389145.
Poynton, T. A. (2005). Computer literacy across the lifespan: A review with implications for educators. *Computers in Human Behavior, 21*, 861–872. https://doi.org/10.

1016/j.chb.2004.03.004.
Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods, 40*, 879–891. 2008 https://doi.org/10.3758/BRM.40.3.879.
Preacher, K. J., & Kelley, K. (2011). Effect size measures for mediation models: Quantitative strategies for communicating indirect effects. *Psychological Methods, 16*, 93–115. https://doi.org/10.1037/a0022658.
R Core Team. (2018). *R: A language and environment for statistical computing.* Vienna, Austria: R Foundation for Statistical Computing. Available online at: https://www.R-project.org/.
Rohatgi, A., Scherer, R., & Hatlevik, O. E. (2016). The role of ICT self-efficacy for students' ICT use and their achievement in a computer and information literacy test. *Computers & Education, 102*, 103–116. https://doi.org/10.1016/j.compedu.2016.08.001.
Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology, 25*, 54–67. https://doi.org/10.1006/ceps.1999.1020.
Sefton-Green, J., Nixon, H., & Erstad, O. (2009). Reviewing approaches and perspectives on “digital literacy”. *Pedagogies: International Journal, 4*, 107–125. https://doi.org/10.1080/15544800902741556.
Snijders, T. A. B., & Bosker, R. J. (2012). *Multilevel analysis: An introduction to basic and advanced multilevel modeling* (2nd ed.). Thousand Oaks: Sage Publications.
Sobel, M. E. (1982). Asymptotic confidence intervals for indirect effects in structural equation models. *Sociological Methodology, 13*, 290–312. https://doi.org/10.2307/270723.
Spante, M., Hashemi, S. S., Lundin, M., & Algers, A. (2018). Digital competence and digital literacy in higher education research: Systematic review of concept use. *Cogent Education, 5*, 1–21. https://doi.org/10.1080/2331186X.2018.1519143.
Staksrud, E., Livingstone, S., Haddon, L., & Ólafsson, K. (2009). *What do we know about children's use of online technologies?A report on data availability and research gaps in Europe* (2nd ed.). London, UK: EU Kids Online. Retrieved from http://eprints.lse.ac.uk/24367/.
Tsitouridou, M., & Vryzas, K. (2011). Digital literacies: Definitions, concepts and educational implications. In L. K. Stergioulas, & H. Drenoyianni (Eds.). *Pursuing digital literacy in compulsory education* (pp. 3–46). New York: Peter Lang.
Vekiri, I. (2010). Socioeconomic differences in elementary students' ICT beliefs and out-of-school experiences. *Computers & Education, 54*, 941–950. https://doi.org/10.1016/j.compedu.2009.09.029.
Verhoeven, J. C., Heerwegh, D., & De Wit, K. (2016). ICT learning experience and research orientation as predictors of ICT skills and the ICT use of university students. *Education and Information Technologies, 21*, 71–103. https://doi.org/10.1007/s10639-014-9310-3.
Vonkova, H., & Hrabak, J. (2015). The (in)comparability of ICT knowledge and skill self-assessments among upper secondary school students: The use of the anchoring vignette method. *Computers & Education, 85*, 191–202. https://doi.org/10.1016/j.compedu.2015.03.003.
Wastiau, P., Blamire, R., Kearney, C., Quittre, V., Van de Gaer, E., & Monseur, C. (2013). The use of ICT in education: A survey of schools in Europe. *European Journal of Education, 48*, 11–27. https://doi.org/10.1111/ejed.12020.
Zylka, J., Christoph, G., Kroehne, U., Hartig, J., & Goldhammer, F. (2015). Moving beyond cognitive elements of ICT literacy: First evidence on the structure of ICT engagement. *Computers in Human Behavior, 53*, 149–160. https://doi.org/10.1016/j.chb.2015.07.008.