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ORIGINAL RESEARCH ARTICLE

A canonical correlation analysis of the influence of access to and use of ICT on secondary school students' academic performance

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This study was conducted to examine the influence of access to and use of information and communication technology (ICT) on academic achievement and motivation. Data were collected from 300 students (12- to 16-year-old; 160 boys) from Sanandaj, Iran. The ICT Familiarity Questionnaire was used to assess the level of students' access to and use of ICT at school and outside of school. Students' Grade Point Average was considered as an indicator of academic achievement and their scores of Academic Motivation Scale as a measure of academic motivation. The findings revealed that students had more access to and use of ICT at home than school. The majority of participants reported that they used digital devices for the first time when they were between 7 and 10 years old. The students spent more time using the Internet outside of school during weekdays. They used digital devices more frequently for general than academic activities. The canonical analysis indicated that ICT-related factors are significantly correlated with academic performance. However, students' access to and use of ICT at school was the most influential factors affecting academic achievement. Furthermore, access to ICT at school and using digital devices at an earlier age were the most contributing factors correlated with academic motivation.

Keywords: use of ICT; access to ICT; canonical correlation; academic achievement; academic motivation

Introduction

Information and communication technology (ICT) refers to a variety of technological tools and resources, including (but not limited to) digital media, digital devices, computers and the Internet, widely used to facilitate acquisition, storage, sharing and utilisation of knowledge. Such technological tools provide teachers and students to access and use a wide range of digital media, including video clips, audio sounds, animation files, visual presentations, articles, podcasts, audiobooks, virtual reality and other kinds of multimedia presentations to enhance teaching and learning quality (OECD 2019).

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Along with growing interest in the use of ICT in education, several international efforts have been directed towards measuring ICT availability and use in education systems across countries around the world. The International Computer and Information Literacy Study (ICILS) was commissioned by the International Association for the Evaluation of Educational Achievement (IEA) to assess students' computer and information literacy that is defined as 'individual's ability to study, work, and live in a digital world' (Fraillon *et al*. 2014, 2020). Likewise, the OECD's Programme for International Student Assessment (PISA) has made it possible to directly measure and compare students' access to and use of ICT (at school and outside of school) across education systems. In the first rounds, starting in 2000, PISA documented various dimensions of access to and use of ICT by 15-year-old students at school and outside of school. In PISA 2000, the students were asked to respond if a computer was available to them in different locations. However, since 2009, PISA has documented the types of ICT resources available to students at home and school separately. Currently, in addition to students' ICT availability and use at school and outside of school, their experience with digital media and devices (or their attitudes towards ICT) is also documented (OECD 2015, 2019).

At the national level, the increasing importance of digital technologies in education systems and the pressing need to equip students with digital competencies have raised major policy concerns for governments (OECD 2019). Accordingly, both developed and developing countries have increased their investments to bring new technologies into students' homes and schools to take advantages of emerging digital technologies in transforming quality of teaching and learning (Barakabitze *et al*. 2019; Conrads *et al*. 2017; Eguavoen 2016; Fidalgo-Neto *et al*. 2009; Liu, Toki, and Pange 2014; Mahboudi, Farrokhi, and Ansarin 2017; Qablan, Abuloum, and Al-Ruz 2009; Rubagiza, Were, and Sutherland 2011).

Similar to that of other developing countries, Iran's education system has adopted several policies to focus on specific strategies in implementing ICT in education. Iran's National ICT Agenda (INICTA) was initiated in 1998 to develop and maintain an advanced technological environment in order to support and enhance education, research, learning, service and administrative activities all over the country, especially in schools. The first phase of INICTA was implemented during a 3-year period during 2002–2004. The total ICT development budget for INICTA for the first phase (2002–2004) was about 550 million dollars, which was, in fact, the first most significant investment on ICT development in the history of Iran (Kousha and Abdoli 2004). Accordingly, Iran's education system encompassed ICT in education and included courses on basic computer skills at primary, lower and upper secondary levels (Iran's Ministry of Education 2014; Mahboudi, Farrokhi, and Ansarin 2017).

Therefore, education systems, including that of Iran, are increasingly embedding digital competencies in their curricula, based on the understanding that digital technologies have made learning possible anytime and anywhere (OECD 2019). However, the literature on the potential impact of ICT adoption on academic performance of students is limited and showing mixed results. On the one hand, there is a body of studies supporting the positive influence of availability and use of ICT on students' academic performance. For instance, Kubiatko and Vlckova (2010) indicated that students having some connection with ICT achieved better scores on the science knowledge test compared with those who were not. Likewise, Mbugua, Kiboss and Tanui (2015) found that the integration of ICT in teaching has had a positive influence on students' academic achievement. On the other hand, there are studies showing a

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lack of relationship, even negative, between ICT use and academic performance. For instance, in his review of the effectiveness of computer-assisted instruction, Hattie (2009) concluded that the effect of this method on learning was neither larger nor smaller than that was seen in other well-intentioned instruction methods, on average. Similarly, Zhang and Liu (2016) indicated that the relationships between different types of ICT use with math and science achievement were negative in the long term, when students' families' socio-economic status was controlled for. Furthermore, a recent study reports that excessive use of technology and social networks, both during weekdays and at weekends, impairs academic performance (Navarro-Martinez and Peña-Acuña 2022).

Therefore, findings from the previous studies have not yet provided a clear answer to the question of whether ICT availability is connected with better student achievement. The inconsistency in the findings of the previous studies may have resulted from several methodological considerations, including differences in data collection methods, developmental and demographic characteristics of the samples, and analytical methods. Indeed, the previous studies have explored correlations between some elements of ICT use and some elements of academic performance and not examined the interactive impact of multiple ICT-related factors (at school and home) on academic performance. In addition, students' academic achievement is not the only measure of their success in school. Research has consistently revealed that academically motivated students tend to perceive school and learning as valuable and enjoy learning-related activities (Rowell and Hong 2018). Such perceptions have a significant and positive direct effect on their academic performance. Thus, given the recognised importance of academic motivation in school success, this study considers academic achievement and academic motivation as the two interlarded dependent variables linked to academic success.

By this understanding, the present study used a canonical correlation analysis method (Sherry and Henson 2005) in order to technically make it possible to identify and analyse the best possible linear relationship between a set of independent variables (ICT-related factors) and a set of dependent variables (academic-related factors).

Research methodology

Study design and sampling

A cross-sectional descriptive survey study was conducted to examine the influence of access to and use of ICT on academic achievement and motivation. The sample was selected from 10 high schools of Sanandaj, Kurdistan, Iran, during the 2018–2019 academic year. Using multi-stage cluster sampling, a total of 310 students were selected from public and private schools to participate in this study. Because of their incomplete questionnaires, 10 participants were excluded, and the questionnaires of 300 students (12- to 16-year-old; 160 boys) included in the analysis. The questionnaires were administered during a school day in the classroom settings, taking 35–40 minutes to be completed. The participants were given required instructions to complete the questionnaires.

The survey was conducted after receiving approval from the institutional ethics committee of the Education Office of Sanandaj (Approval code: 5800/109297/5300; date: 2019-03-14). The participants were provided with a brief explanation of the study purposes, and an informed consent of each participant was *obtained* prior to the data collection.

Data collection and analysis tools

The ICT familiarity questionnaire (OECD 2015) was used to measure students' access to and use of ICT at school and outside of school. The first section of the questionnaire included questions on whether or not students had access to ICT devices such as a desktop computer, Internet connection, a printer or an e-book reader in their homes and schools, and if so, whether they used them. The second section included questions about the age of students when they first had access to and used digital technologies, computers and the Internet. The third section asked students to indicate the length of time they spent on using the Internet at school and outside of school during both a typical weekday and a typical weekend. The fourth section consisted of questions on how often students used digital devices for general and academic purposes at school and outside of school. Finally, the fifth section asked students to think about their experience with digital media and digital devices and indicate whether or not they agreed with related statements.

Academic motivation was measured using the Persian version of Academic Motivation Scale (Bahrani 2009). It consisted of 33 items on a five-point Likert scale ranging from 1 (never) to 5 (almost always). Student's level of academic motivation was calculated by summing up the scores of all items, higher scores indicating higher academic motivation.

A semester Grade Point Average (GPA) score was computed as the measure of students' academic achievement. The research team asked the executive boards of schools to enclose a copy of GPA score of the first semester for each student when completing the questionnaires.

Canonical correlation analyses were conducted to examine the linear relationships between a set of ICT-related variables and a set of academic-related variables and to explain the type of relationships that may exist between and within these two sets of variables.

Results

Descriptive statistics

Descriptive statistics summarised in Table 1 indicates that students had more access to and use of ICT at home than at school. The majority of participants reported that they used digital devices for the first time when they were between 7 and 10 years old. During a typical weekday, students spent more time using the Internet outside of school than inside school and more time using the Internet during a typical weekend than a weekday. They used digital devices for academic activities outside of school more frequently than inside school and used digital devices for general activities more frequently than for academic purposes. The participants have shown relatively high scores in their experience with digital media and digital devices. Furthermore, the study participants obtained high mean scores in both academic achievement and academic motivation measures.

Correlation coefficients

The results of Table 2 represent a significant positive relationship between access to and use of ICT at home and school with academic achievement at the p-value of <0.01. It means that access to ICT at home and school directly influences academic

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Table 1. Descriptive statistics for ICT-related factors and academic-related factors.

		N	Min	Max	Mean	SD
Independent variables						
Access to ICT	At home	300	0.00	11.00	6.19	2.27
	At school	300	0.00	8.00	4.93	2.19
Use of ICT	At home	300	0.00	10.00	5.12	2.36
	At school	300	0.00	8.00	3.36	2.01
Age of first access to	Digital devices	300	5.00	14.00	8.56	3.05
	Computer	300	5.00	14.00	8.77	3.04
	The internet	300	5.00	14.00	10.89	2.48
Length of time using the Internet during a weekday	At school	300	0.00	420.00	16.85	50.12
	Outside school	300	0.00	420.00	82.60	108.33
Length of time using the Internet during a weekend	Outside school	300	0.00	420.00	86.10	109.94
Frequency use of digital devices for academic activities	At school	300	0.00	30.00	6.75	9.86
	Outside school	300	0.00	27.00	2.76	4.97
Frequency use of digital devices for general activities	Outside school	300	0.00	30.00	0.68	3.44
Experience with digital media and devices		300	24.00	82.00	58.13	10.49
Dependent variables						
Academic motivation		298	51.00	159.00	113.68	16.07
Academic achievement		300	13.62	20.00	18.48	1.39

Note: The values for access to ICT at home and school indicate the number of digital media and devices (including desktop computers, laptops, notebooks, smartphones, tablet computers, cell phones without Internet access, game consoles, Internet-connected television and other digital devices) that students accessed regardless of whether they were used. The values for ICT at home and school are the number of those media and devices that students used.

The values for the age of first access to digital devices, computer and the Internet were scored based on the Likert-scale ratings, scored from 1 to 5 (6 years old or younger = 1; 7–9 years old = 2; 10–12 years old = 3; 13 years old or older = 4; never used a digital device until today = 5). Then, these categorical values were converted into a numeric scale by converting the time intervals into average times as 5, 8, 11 and 14, respectively. The final category was not included because none of the participants had selected this category.

The lengths of time students used the Internet during a typical weekday and weekend at school and outside of school were scored based on the Likert-scale ratings ranging from 1 to 7 (no time = 1; 1–30 minutes per day = 2; 31–60 minutes a day = 3; between 1 and 2 hours per day = 4; between 2 and 4 hours per day = 5; between 4 and 6 hours per day = 6; more than 6 hours per day = 7). Then, these categorical values were converted into a numeric scale by converting the time intervals into average time duration in minutes, as 0, 15, 45, 90, 180, 300 and 420 minutes, respectively.

The frequency of using digital devices represents how often students used digital devices for academic activities at school (including nine activities such as doing homework on a school computer), for academic activities outside of school (including 12 activities such as browsing the Internet for schoolwork) and for general activities outside of school (including 12 activities such as playing games). The answers were scored based on the Likert-scale ratings ranging from 1 to 5 (never or hardly ever = 1; once or twice a month = 5; once or twice a week = 3; almost every day = 4; every day = 5). Then, these categorical data were converted into numerical values by counting the percentage of each category in terms of a month, as 0 = never, 2 = 1.5% of a month, 6 = 20% of a month, 27 = 90% of a month and 30 = 100% of a month.

Students' experience with digital media and devices was obtained by calculating the mean of the 15 items that asked students to think about their experience with digital media and digital devices. Each item scored from 1 to 4 (strongly disagree = 1; disagree = 2; agree = 3; strongly agree = 4). Total score was obtained from the sum of scores of all items.

Academic motivation was assessed through an academic motivation scale, which consisted of 33 items on a five-point Likert scale ranging from 1 (never) to 5 (almost always). Total score was obtained from the sum of scores of these 33 items.

The values for academic achievement were the overall mean scores of students obtained from their semester GPA score.

Table 2. Correlation coefficient for ICT-related factors and academic-related factors.

Independent variables		Dependent variables	
		Academic achievement	Academic motivation
Access to ICT	At home	0.169**	0.106
	At school	0.38**	0.037
Use of ICT	At home	0.151**	0.104
	At school	0.376**	0.115*
Age of first access to	Digital devices	−0.101	0.030
	Computer	−0.125*	0.031
	The internet	−0.068	0.060
The length of time using Internet during a weekday	At school	0.057	−0.013
	Outside school	−0.043	−0.174**
The length of time using Internet during a weekend	Outside school	0.042	−0.062
The frequency of using digital devices for academic activities	At school	−0.002	−0.030
	Outside school	−0.026	−0.026
The frequency of using digital devices for general activities	Outside school	−0.011	−0.034
Experience with digital media and devices		−0.004	−0.076

*p-value < 0.05, **p-value < 0.01.

Table 3. Multivariate test of significance.

Variates	Canonical correlation	Eigen value	Wilk statistic	F distribution (F-value)	Hypoth. DF	Error DF	P-value
1	0.458	0.265	0.719	3.619	28	564	0.000
2	0.301	0.100	0.909	2.174	13	283	0.011

achievement. There is also a positive relationship between the use of ICT at school with academic motivation at the p-value of <0.05. This also means that when the use of (not access to) ICT at school increases, academic motivation increases. However, there is a negative relationship between the age of first using computers and academic achievement at the p-value of <0.05. Accordingly, using computers at an earlier age associates with higher academic achievement scores. Also, there is a negative relationship between the length of time using the Internet during a typical weekday outside of school with academic motivation at the p-value of <0.05. It means that the longer the time students use the Internet during a typical weekday, the lower their academic motivation is.

Canonical correlation analysis

In this study, the number of independent variables was 16, and the number of dependent variables was 2, and thus, the number of possible canonical variates is 2.

As Table 3 shows, Wilk's test of significance revealed that the two canonical correlations computed in the canonical analysis were significant [Wilk statistic = 0.719, F (28, 564) = 3.619 p < 0.000; Wilks's statistic = 0.909, F (28, 564) = 2.174, p < 0.05,

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respectively]. The first eigenvalue and its corresponding canonical correlation coefficient estimate were 0.265 and 0.458, respectively. The second eigenvalue and its corresponding canonical correlation coefficient estimate were 0.100 and 0.301, respectively. This implies that 72.6% of the total variance of independent and dependent variables is shared in the first variate pair of linear weighted combination and 27.4% of the total variance in the second pair.

The canonical loadings (also called structure coefficients) are conducted to analyse the correlation between the canonical variates and the variables in the same domain (Table 4).

As a rule of thumb, canonical loadings greater than 0.30 could be treated as meaningful (Pedhazur 1997). The results of the first variate pair of independent set showed that use of ICT at school (−0.81), access to ICT at school (−0.80), access to ICT at home (−0.38) and use of ICT at home (−0.34) were the most influential variables amongst the ICT-related factors. Considering the second variate pair, the length of time using the Internet outside of school during a typical weekday (0.54), access to ICT at school (0.39) and the age at first use of the Internet (0.30) were the most influential variables.

For the first pair of dependent sets, the mean score of academic achievement (−0.995) was more influential than academic motivation in explaining the level of academic achievement. For the second pair, the mean score of academic motivation (−0.918) was more influential than academic motivation in explaining the level of academic performance.

Table 4. Canonical loadings.

		Canonical loadings	
		1	2
Independent set	Access to ICT at home	−0.38	−0.12
	Access to ICT at school	−0.80	0.39
	Use of ICT at home	−0.34	−0.14
	Use of ICT at school	−0.81	0.12
	Age of first access to digital devices	0.21	−0.25
	Age at first use of computer	0.26	−0.28
	Age at first use of Internet	0.13	−0.30
	The length of time using Internet at school during a weekday	−0.11	0.12
	The length of time using the Internet outside school during a weekday	0.13	0.54
	The length of time using the Internet outside school during a weekend	−0.075	0.27
	The frequency of time using digital devices outside school for general activities	0.020	0.10
	The frequency of time using digital devices outside school for academic activities	0.061	0.05
	The frequency of time using digital devices at school for academic activities	0.010	0.10
	Experience with digital media and devices	0.021	0.26
	Academic achievement	−0.99	0.10
	Academic motivation	−0.39	−0.91

The canonical cross loadings were analysed to explore the correlation between individual variables and the linear combination of the opposite set of variables. The cross loadings greater than 0.30 could be treated as significant.

The canonical cross-loadings in Table 5 show that the proportion of use of ICT at school (−0.375) and access to ICT at school (−0.370) forming the first variate pair and the age at first use of digital devices (−0.879) forming the second variate pair were found to contribute highly to the levels of scores in academic factors. Also, academic achievement had a significant and higher contribution (−0.46) than academic motivation with the first independent pair of ICT factors.

The results of analysis of variance of the canonical variates summarised in Table 6 show the amount of variance accounted for in one set of variables by the other set.

Table 6 shows that 57% of the variance of the dependent variables (academic-related variables) was explained by the first linear weighted combination of independent variables (first canonical variate), and the percentage for the second canonical variate was 42%. However, only 12% of the variance of independent variables

Table 5. Canonical cross loadings.

		Canonical cross loadings	
		1	2
Independent set	Access to ICT at home	−0.177	−0.039
	Access to ICT at school	−0.370	−0.119
	Use of ICT at home	−0.160	−0.044
	Use of ICT at school	−0.375	0.036
	Age at first use of digital devices	0.09	−0.879
	Age at first use of computer	0.123	−0.086
	Age at first use of the Internet	0.063	−0.093
	The length of time using the Internet at school during a weekday	−0.054	0.037
	The length of time using the Internet outside school during a weekday	0.061	0.163
	The length of time using the Internet outside school during a weekend	−0.034	0.082
	The frequency of time using digital devices outside school for general activities	0.009	0.033
	The frequency of time using digital devices outside school for academic activities	0.028	0.016
	The frequency of time using digital devices at school for academic activities	0.004	0.031
	Experience with digital media and digital devices	0.010	0.078
	Academic achievement	−0.46	0.031
	Academic motivation	−0.18	−0.23

Table 6. Analysis of variance for the canonical variates.

Canonical variates	Set 2 by Set 1	Set 2 by self	Set 1 by Set 2	Set 1 by self
1	0.127	0.027	0.573	0.120
2	0.066	0.006	0.427	0.039

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(ICT-related variables) was explained by the first linear weighted combination of dependent variables (first canonical variate), and the percentage for second canonical variate was 6.6%. These findings imply that a high degree of the percentage of the variances in the academic variables is explained by ICT variables.

Discussion

The motivation for conducting this study was a lack of clarity in educational research about the influence of availability and use of ICT on students' academic performance. Canonical correlation analysis was performed on an ICT data set consisting of the 16 factors, and an academic data set that included academic achievement and academic motivation. Two significant canonical variate pairs were extracted in the canonical correlation analysis of the ICT and academic data sets. Correlation between the first canonical variates was 0.458, indicating a moderate relation between the ICT and academic variables and accounting for 72.6% of the total information contained in the overall canonical correlation (Table 3). The second canonical correlation was significant (0.301) but explained only 27.4% of the total information contained in the overall canonical correlation (see Table 3). Such findings are in line with the previous studies, showing the positive effects of computer use on students' mathematical performance (Demir and Kilic 2009), the positive relationship between ICT use and students' science knowledge score (Kubiatko and Vlckova 2010) and positive influence of the integration of ICT in teaching on students' academic performance (Mbugua, Kiboss, and Tanui 2015).

One of the more significant findings to emerge from this study is that, whereas students had more access to and use of ICT at home than at school (see Table 1), the access to and use of ICT at school have shown the greatest relationship with academic achievement, as evidenced by the canonical cross loadings (see Table 5). Consistent with these results, previous studies have reported positive relationships between students' use of ICT at school and academic performance (e.g. James *et al*. 2000; Kubiatko and Vlckova 2010; Weaver 2000). For example, Kubiatko and Vlckova (2010) revealed that students whose ICT activity was connected with the educational activities achieved a higher science knowledge score compared with students whose ICT activity was not connected with the educational purposes. According to reports of UNESCO Institute for Statistics (UIS 2014), Iranian students who used school computers to supplement learning had higher average achievement scores in mathematics and science than those with no school-based computers (as cited in Mahboudi, Farrokhi, and Ansarin 2017). Also, Skarin (2008) evidenced that the use of ICT at school had considerable positive effects not only on test scores but also on students' motivation in collaborative work.

Whilst the findings support the positive impact of use of technology at school on learning outcomes, there was a negative relationship between the lengths of time using Internet outside of school during weekdays and academic motivation (see Table 2). Also, the results of canonical loadings (Table 4) confirmed that this factor is the most influential variable amongst the ICT-related factors (0.54), which specifically correlated with academic motivation. This is consistent with the findings obtained from a recent study that suggests the amount of time children spend online should be limited, as in most cases, excessive use leads to poor academic performance (Navarro-Martinez and Peña-Acuña 2022).

In addition, the finding highlights the link between the use of ICT at school with academic motivation as well as academic achievement (see Table 2). It means that student's access to and use of ICT lead to positive motivational outcomes and subsequently foster their activity and engagement (Passey *et al*. 2004). Indeed, when children have access to and use computers, they are more likely not only to have a social networking site but also to spend more time communicating and interacting with their peers (Fairlie and Kalil 2017). Such possibilities can ultimately strengthen educational outcomes and enhance students' academic achievement. However, the schools that are well-equipped with computers and other forms of ICT also tend to be from regions of higher socio-economic status (SES), a factor that is consistently positively related with academic achievement (Mahboudi, Farrokhi, and Ansarin 2017).

Furthermore, according to the results of the canonical analysis, the age of the first use of digital devices was the highest correlated variable with the variables in the academic set (see Table 5). Also, the results of the pairwise correlation (Table 2) showed that there is a negative association between early uptake of digital devices and academic results. Such findings are consistent with the result of a current research conducted by Juhaňák *et al* (2019) that showed that children who start using a computer at a later age demonstrate significantly lower ICT competence and ICT autonomy at the age of 15.

Conclusion

Based on the results of the present study, the most contributing ICT-related factors in explaining the level of academic performance are availability and use of ICT at schools. That is, students in schools with greater access to and use of ICTs perform better in academic achievement examinations. However, it is reported that Iran has a significantly lower level of diffusion and use of ICT than that of the developed countries (Mahboudi, Farrokhi, and Ansarin 2017). Therefore, it seems important to help schools to equip classrooms with adequate resources and help teachers to enrich their instruction with new digital devices and media. There is an urgent need to assist schools to play an important role in narrowing the digital divide (Dolan 2016; Nouri *et al*. 2021) by making ICT equipment and Internet connectivity available for every classroom and encouraging students to improve their digital capabilities.

It should also be highlighted that the present study examined the canonical correlation between a set of ICT-related factors with a set of academic-related variables. Future research should investigate the mediating roles of socio-cultural factors on the relationship between access to and use of ICT and academic performance. Furthermore, the ICT familiarity questionnaire is a useful instrument for collecting detailed information related to access, use and attitudes towards ICT amongst students both at home and at school, and thus, there is a need to identify and address the psychometric limitations of the questionnaire in terms of reliability, validity and norming.

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