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Computer Use in Math Lessons: Evidence from a Global Survey

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Abstract

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Prior research has suggested an increasing use of information and communication technology in education during the last two decades with mixed support for the positive effect of such use on student literacy. This study examined the use of computers in math lessons for tasks such as drawing graphs, performing calculations, and data entry using a large scale sample of high school old students from 43 countries. Empirical results indicate that despite significant differences in economic, social, and cultural dimensions among surveyed countries, there is little difference in computer use in math lessons between students in OECD and non-OECD countries. Implications are discussed. For future research in this area we suggest two courses of action. First, our study can be replicated with a different sample of countries, subject areas, and students, in order to expand the evidence base for computer use in formal education. Second, our method can be replicated at country level in order to identify country-specific factors of ICT use in the classroom. Given the usually significant differences in economic, social, and cultural atmosphere across countries, this set of factors is likely to differ across countries.

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Introduction

The last two decades have seen an increasing adoption of information and communication technology (ICT) in most countries across the world (Balaban et al., 2023; Napierala & Kvetan, 2023). For instance, between 1990 and 2015 the mean number of internet users per 100 persons in the world grew from a mere 0.2 to 47.4 (United Nations, 2016; see Figure 1). According to another report, between the years 1988 and 2006 the average number of personal computers per 100 persons in the world increased eightfold from 2.9 to 23.2 (The World Bank, 2018a; see Figure 2). There has been a similar pervasiveness of ICT tools such as computers, interactive whiteboards, data projectors, and broadband access in education from the K-12 environment to colleges and universities throughout the world (European Union, 2014; OECD, 2000; OECD, 2005; Wachira & Keengwe, 2011). For almost all countries ICT integration in education is now a matter of policy as ICT does not only facilitate new forms of teaching and learning but also because the competitive nature of modern life requires young men and women to be ICT-literate as they finish their compulsory schooling and enter adulthood to become productive workers (European Union, 2014; OECD, 2005; Kozma, 2008; Rha & Yoshida, 2005; Yusuf, 2005). One of the most widely used ICT tools in education is the personal computer equipped with Internet access and applications for students both inside and outside the classroom (OECD, 2000; Livingstone, 2012). According to a study commissioned by the European Commission, the average number of students per computer in schools situated within the European Union is between three and seven with nine out of ten students enrolled in a school that has access to broadband (European Union, 2013).

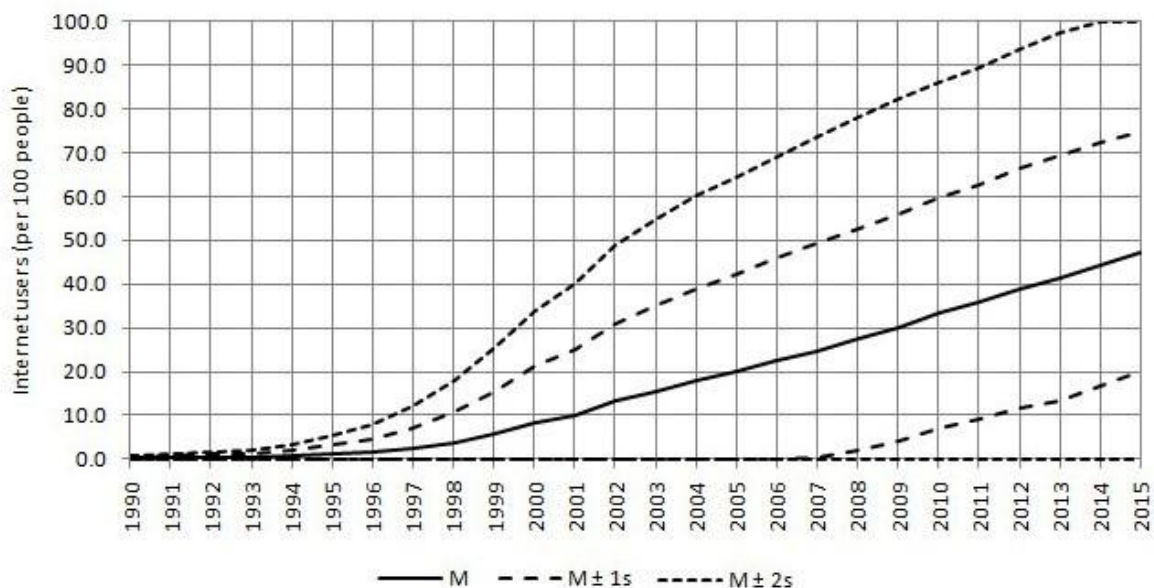


Figure 1. Time Series Chart of Mean Number of Internet Users (per 100 people) in the World for the Period 1990–2015. Solid line: M ; Long-dashed line: $M \pm 1SD$; Short-dashed line: $M \pm 2SD$. For $M - 1SD$ and $M - 2SD$, negative values rounded up to 0; for $M + 2SD$, values over 100 rounded down to 100. Data source: The World Bank (2018b).

However, such widespread availability of computers does not necessarily translate into corresponding increase in

their use by students and teachers (Cuban, Kirkpatrick, & Peck, 2001; Livingstone, 2012; Wachira & Keengwe, 2011; Wastiau et al., 2013). A European Union survey for instance suggests that mainstreaming of ICT in education "remains a challenge," and that "dynamic and interactive pedagogical practices are not widespread in most countries" (European Union, 2014). Prior research has suggested several reasons for this slow ICT adoption in schools. These reasons include lack of teacher training (Gudmundsdottir, 2010; Koedinger & Anderson, 1993; Wastiau et al., 2013), lack of economic resources (OECD, 2000; OECD, 2005), actual or perceived low quality of locally available ICT tools (Cuban et al., 2000; Wachira & Keengwe, 2011), lack of technology support (Strudler & Herrington, 2008), lack of technology leadership (Dexter, 2008; Wachira & Keengwe, 2011), cultural factors such as language barriers (Gudmundsdottir, 2010), teacher self-efficacy and innovativeness in information technology (Hong et al., 2022), skepticism among teachers about ICT usefulness in the classroom (Livingstone, 2012; Wastiau et al., 2013), rigid teaching schedules (Cuban et al., 2000), lack of collaborative school environment (European Union, 2014) and weakness of empirical evidence linking ICT use to student outcomes such as literacy and achievement (Dunleavy & Heinecke, 2007; Livingstone, 2012). The slow ICT adoption in schools is especially a concern in developing economies where a lower availability of ICT resources exacerbates the problem and has the potential to widen the so-called digital divide between these economies and their wealthier counterparts. The digital divide in turn raises equity concerns for vulnerable student populations such as those with physical disabilities, special needs, ethnic minorities, and economically disadvantaged groups (OECD, 2000).

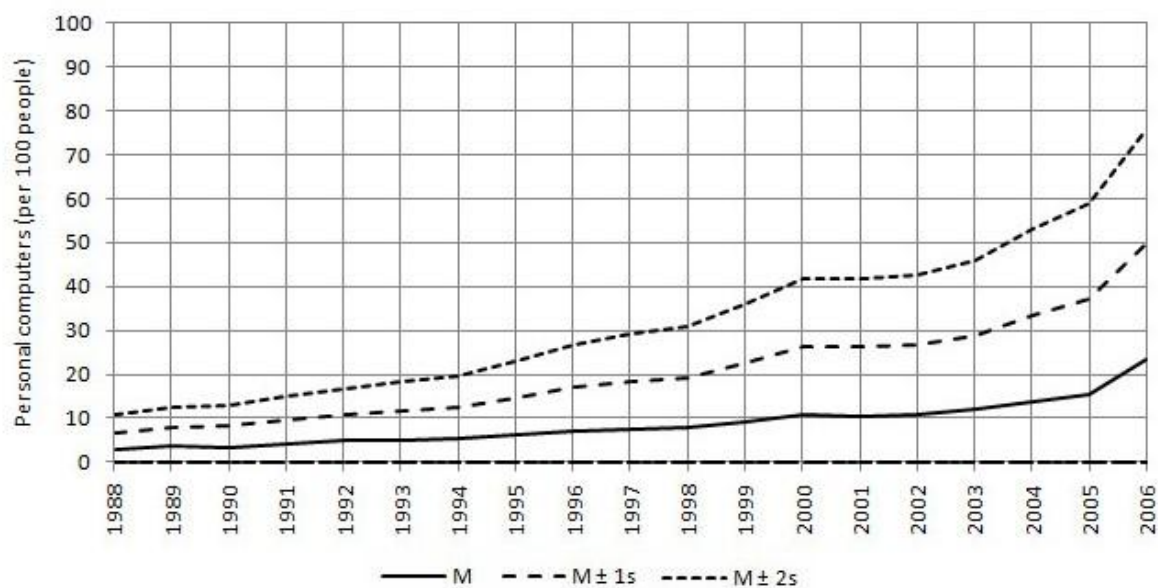


Figure 2. Time Series Chart of Mean Number of Personal Computers (per 100 people) in the World for the Period 1988–2006. Solid line: M ; Long-dashed line: $M \pm 1SD$; Short-dashed line: $M \pm 2SD$. For $M - 1SD$ and $M - 2SD$, negative values rounded up to 0. Data source: The World Bank (2018a).

Among the various literacy domains that can benefit from ICT integration in the classroom, one core domain is mathematics. ICT integration in math lessons can take several forms ranging from individual and collaborative educational games (Kebritchi, Hirumi, & Bai, 2010; Lopez-Morteo & López, 2007) to coordinating school tasks

with homework (Fuchs & Woessmann, 2004; Lopez-Morteo & López, 2007) to routine activities such as data entry, construction of basic graphs and solving systems of equations (Dunleavy & Heinecke, 2007).

Motivated by prior research reviewed in this section, in order to understand how computers are used in math lessons across the world and whether or not such use differs between rich and poor nations, the current study exploits a large scale international sample. The use of a uniform set of survey items administered in nationally representative samples allows statistical results to be comparable across groups of countries. The specific research question being evaluated is whether or not on account of their status as developed economies with generally high national incomes, computers are used in math lessons more extensively in schools situated within the OECD bloc as compared to their non-OECD counterparts.

Methodology

Sample and Participants

The sample used in this study was extracted from student data file for the Program of International Student Assessment. This is a large scale cross country assessment of literacy of 15-year old students in areas such as mathematics, reading, and science. Countries that participate in PISA include both Organization for Economic Cooperation and Development (OECD) member and non-member states. Although OECD oversees the survey, actual administration within the countries is carried out by respective national government agencies.

In addition to the assessment component, the survey collects information about student attitudes, beliefs, perceptions, and practices related to ICT use using a separate questionnaire. However, not all countries participate in the ICT survey. For instance in our sample, out of the 68 economies that participated in the survey, only 43 provided student responses related to ICT items. We use the term economy here to emphasize that not all participating regions are independent countries. Some regions such as Hong Kong (China), Perm (Russian Federation), and Florida (USA) are actually autonomous or semi-autonomous regions within independent countries. The 68 economies in our sample are representative of 62 sovereign countries. Having made this distinction here, in the remainder of this study we use the two terms interchangeably.

An attractive feature of our samples is that they are representative at the country level. Thus, findings from a country level sample can be generalized to the entire population of 15-year old students in that country. In order to ensure that samples are representative of their target populations, country level samples were selected using a complex two-stage stratified random selection scheme. In this scheme, a random sample of schools is selected in the first stage which is followed by a random selection of students within each selected school in the second stage. The full sample included 485,490 students from 68 economies. After excluding countries that did not participate in the ICT component, this number was reduced to 285,082. This sample size is representative of a target population of 9,103,198 ($M = 211,702$, $SD = 311,435$) fifteen-year old students in 43 economies. The large standard deviation value relative to the mean indicates presence of countries such as Japan, Mexico, and the Russian Federation with very large populations (each representing more than one million 15-year old students).

Measures

Use of computers in math lessons: A total of seven items (see Table 1) were used to collect information from students about their use of computers in math lessons. A sample item included, "Within the last month, has a computer ever been used for the following purpose in your mathematics lessons? Constructing geometric figures (e.g. an equilateral triangle with given side lengths)." Responses choices for all items were 1 (Yes, students did this), 2 (Yes, but only the teacher demonstrated this), and 3 (No). Thus, higher item response scores are indicative of less use of computers in math lessons. The reliability among these seven items was high with Cronbach's alpha being .93 for non-OECD countries and .91 for OECD countries. Inter-item correlations (see Table 2) ranged from a minimum of .54 to a maximum of .75 ($M = .66$, $SD = .07$) for non-OECD countries, and from a minimum of .50 to a maximum of .72 ($M = .61$, $SD = .06$) for OECD countries. Within each group of countries, the means and standard deviations of item responses were very similar (see Table 3). Response percentages for each item were highest for category 3, which indicated no computer use in math lessons.

OECD indicator. This is a dichotomous nominal variable that takes a value of 1 for OECD countries and a value of 0 for non-OECD countries. Out of 43 economies represented in our sample, 29 were OECD members ($n = 224,764$) while the rest were non-members ($n = 60,318$).

Table 1. Items Measuring Computer Use in Math Lessons

Within the last month, has a computer ever been used for the following purposes in your mathematics lessons?
1. Drawing the graph of a function (such as $y = 4x+6$).
2. Calculating with numbers (such as calculating $5*233/8$).
3. Constructing geometric figures (e.g. an equilateral triangle with given side lengths).
4. Entering data in a spreadsheet (e.g. in Excel).
5. Rewriting algebraic expressions and solving equations (such as $a^2+2ab+b^2$).
6. Drawing histograms (a graph that shows the distribution of frequencies of data).
7. Finding out how the graph of a function like $y=ax^2$ changes depending on a .

Note. $n = 285,082$ (OECD, 224764; non-OECD, 60318). Cronbach's alpha = .92 (OECD, .91; non-OECD, .93). Response categories for each item were 1 (Yes, students did this), 2 (Yes, but only the teacher demonstrated this), and 3 (No).

Table 2. List of Economics included in the Sample

Non-OECD economies, $n = 224,764$		OECD economies, $n = 60,318$		
Chinese Taipei	Serbia	Australia	Hungary	Norway
Costa Rica	Shanghai (China)	Austria	Iceland	Poland
Croatia	Singapore	Belgium	Ireland	Portugal
Hong Kong (China)	Uruguay	Chile	Israel	Slovak Republic
Jordan		Czech Republic	Italy	Slovenia
Latvia		Denmark	Japan	Spain

Non-OECD economies, $n = 224,764$	OECD economies, $n = 60,318$		
Liechtenstein	Estonia	Korea	Sweden
Macao (China)	Finland	Mexico	Switzerland
Perm (Russian Federation)	Germany	Netherlands	Turkey
Russian Federation	Greece	New Zealand	

Table 3. Correlations among Items Measuring Computer Use in Math Lessons

Item	Pearson Correlation, r						
	1	2	3	4	5	6	7
Non-OECD economies							
1. Draw graph	–						
2. Calculation with numbers	.68***	–					
3. Geometric figures	.71***	.69***	–				
4. Spreadsheet	.54***	.58***	.58***	–			
5. Algebra	.72***	.72***	.73***	.57***	–		
6. Histograms	.61***	.62***	.65***	.66***	.65***	–	
7. Change in graphs	.74***	.65***	.70***	.55***	.75***	.67***	–
OECD economies							
1. Draw graph	–						
2. Calculation with numbers	.65***	–					
3. Geometric figures	.64***	.62***	–				
4. Spreadsheet	.51***	.55***	.52***	–			
5. Algebra	.68***	.66***	.66***	.51***	–		
6. Histograms	.57***	.57***	.59***	.60***	.60***	–	
7. Change in graphs	.71***	.61***	.64***	.50***	.72***	.63***	–

Note. $n = 285,082$ (OECD, 224764; non-OECD, 60318). Cohen's (1992) cutoffs for r : small effect, .1; medium effect, .3; large effect, .5.

* $p < .05$. ** $p < .01$. *** $p < .001$.

Analytical Method

In order to see if there was a significant difference in mean computer use in math lessons between OECD and non-OECD countries, we employed independent samples t test. The choice of this method is justified because within each group of countries students are expected to have similar variation on characteristics such as gender, grade, and socioeconomic status. We performed a separate t test on each of the seven items included in this study. Since our sample size is very large we expect even small differences in means to turn out as statistically significant. In order not to read too much into statistical significance we also computed Cohen's d based on a pooled standard deviation separately for each item. The expression for d and pooled standard deviation, SD_p are given by (1) and (2).

$$Cohen's\ d = \frac{|M_{OECD} - M_{non-OECD}|}{SD_p} \quad (1)$$

$$SD_p = \sqrt{\frac{(n_{OECD} - 1) \times SD_{OECD}^2 + (n_{non-OECD} - 1) \times SD_{non-OECD}^2}{n_{OECD} + n_{non-OECD} - 2}} \quad (2)$$

Using general linear model notation, the independent samples t test model is given by the expression in (3).

$$Y_{ij} = \alpha_j + \beta_j X_i + \varepsilon_{ij} \quad (3)$$

where Y_i is the item response score of student i on item j ; there are $J = 7$ items; α_j is the mean student response on item j for non-OECD countries; β_j is the difference in means on item j between non-OECD and OECD countries; X is the OECD indicator variable that takes a value of 0 for non-OECD countries and a value of 1 for OECD countries; and ε_{ij} is the student- and item-specific error term.

We evaluated the underlying assumptions of normality, homogeneity of variance, and independence for each item. The normality assumption was automatically satisfied because our sample sizes for each group exceeded 30. The central limit theorem ensures that under such circumstances the sampling distribution of sample means is approximately normal. The independence assumption is valid because sample selection was based on a random process. The homogeneity of variances assumption was tested with Levene's test and failed for all seven items. In order to counter this issue we used Welch adjustment with adjusted degrees of freedom for the t test. In order to interpret reported effect sizes, we used cutoffs recommended by Cohen (1992). All tests of hypotheses were evaluated at .05 level of significance, and all computations were performed with IBM SPSS Statistics.

Results

Pearson correlations and descriptive statistics for the seven items measuring computer use in math lessons are presented separately for OECD and non-OECD countries in Tables 3 and 4 respectively. Estimates presented in Table 3 show high correlations among the seven items. This suggests that when computer is used in math lessons, such use is not restricted to any one activity. Similarly, when computer is not used in math lessons, that lack of use is also somewhat universal. Given the large sample sizes used in this study, we expect the correlations to be significant even when they are only marginally different from zero. For this reason we need to look at effect sizes. As figures in table 3 show, all reported correlations exceed .5 which according to cutoffs recommended by Cohen (1992) are classified as large effect sizes.

Descriptive statistics presented in Table 4 suggest that the pattern of responses on the seven items that measured computer use in math lessons was very similar between OECD and non-OECD countries (see Figure 3). This includes response percentages for each category of the seven administered items, as well as item means and standard deviations. In both groups of countries, a majority of students indicated that they did not use computer in math lessons for all seven items, with the percentage of responses for category 3 (No) all exceeding 50%. The response percentages were slightly higher for category 1 (Yes, students did this) as compared to category 2 (Yes, but the teacher demonstrated this) suggesting that when computer was used in math lessons, that use was

associated with students. We do note however, that in some cases (e.g. items 6 and 7 for OECD countries) the difference in percentages reported for category 1 and 2 tended to be small (e.g. the difference is only 0.8% for item 6).

Results from the independent samples t tests for the mean difference in seven item responses between OECD and non-OECD countries is presented in Table 5. Negative values on the t statistic or the mean difference are indicative of a higher mean for OECD countries. For all seven items the observed value of the t statistic was highly significant suggesting that there is a significant mean difference between OECD and non-OECD countries on all seven items. However, we again note that such patterns of high significance are expected when sample sizes are large. This is so because large sample sizes suppress standard errors of parameter estimates. This in turn has the effect of inflating the observed value of test statistics such as the t statistic. For this reason, rather than relying on statistical significance alone we should also examine effect sizes.

Table 4. Descriptive Statistics for Items Measuring Computer Use in Math lessons

Item	<i>M</i>	<i>SD</i>	1 (Yes, students did this), %	2 (Yes, but only the teacher demonstrated this), %	3 (No), %
Non-OECD economies					
1. Draw graph	2.46	0.78	18.2	17.8	64.1
2. Calculation with numbers	2.55	0.76	16.7	11.7	71.7
3. Geometric figures	2.50	0.77	16.8	16.7	66.5
4. Spreadsheet	2.50	0.78	18.2	13.2	68.7
5. Algebra	2.54	0.76	16.5	13.2	70.3
6. Histograms	2.56	0.73	14.4	15.0	70.6
7. Change in graphs	2.52	0.74	15.0	17.7	67.3
OECD economies					
1. Draw graph	2.54	0.76	16.5	13.1	70.4
2. Calculation with numbers	2.59	0.73	14.9	10.9	74.2
3. Geometric figures	2.57	0.73	14.6	13.3	72.1
4. Spreadsheet	2.47	0.81	20.2	12.2	67.6
5. Algebra	2.60	0.72	14.0	11.9	74.1
6. Histograms	2.62	0.70	12.9	12.1	75.1
7. Change in graphs	2.62	0.70	12.9	12.6	74.5

Note. Higher item scores indicate lesser use of computers in math lessons.

Table 5. Independent Samples t Test Results for mean Difference in Items Measuring Computer Use in Math Lessons between Non-OECD and OECD Economies

Item	<i>t</i>	<i>df</i>	<i>p</i>	ΔM	<i>LL</i>	<i>UL</i>	<i>d</i>
1. Draw graph	-22.38	93220.94	< .001	-0.08	-0.09	-0.07	0.10
2. Calculation with numbers	-12.27	92637.25	< .001	-0.04	-0.05	-0.04	0.06
3. Geometric figures	-22.22	92191.61	< .001	-0.08	-0.08	-0.07	0.10
4. Spreadsheet	8.50	97551.71	< .001	0.03	0.02	0.04	0.04
5. Algebra	-17.97	91552.06	< .001	-0.06	-0.07	-0.06	0.08
6. Histograms	-17.86	92385.25	< .001	-0.06	-0.07	-0.05	0.08
7. Change in graphs	-27.48	91582.78	< .001	-0.09	-0.10	-0.09	0.13

Note. $n = 285,082$ (OECD, 224764; non-OECD, 60318). Cohen's (1992) cutoffs for *d*: small effect, .02; medium effect, .5; large effect, .8. Higher item scores indicate lesser use of computers in math lessons. Cohen's *d* is based on pooled standard deviation. *df* values are based on the assumption of heterogeneous group variances. CI = confidence interval. *LL* = lower limit. *UL* = upper limit.

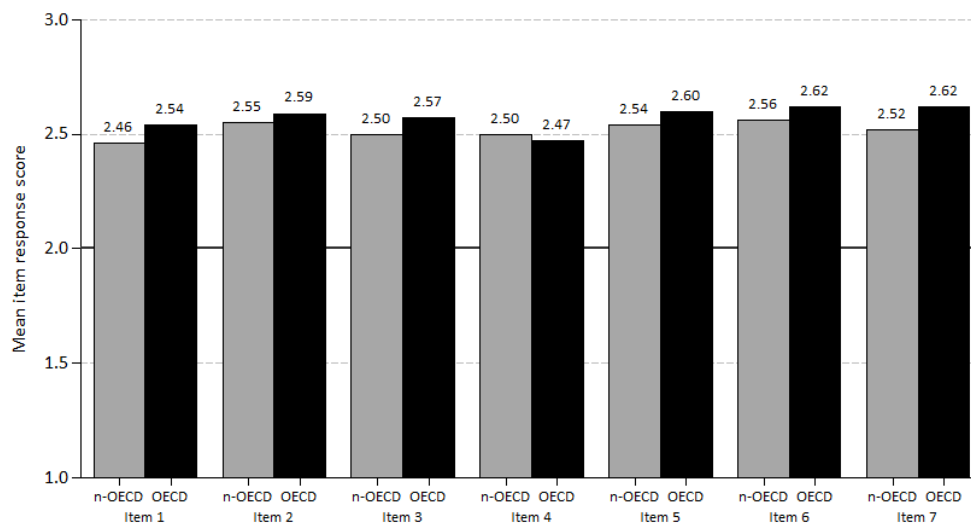


Figure 3. Bar Chart of Mean Scores for Items Measuring Computer Use in Math Lessons with Separate Bars for OECD (dark shaded) and Non-OECD (light shaded) Countries. Solid horizontal line at $Y=2$ indicates median response category. n-OECD = non-OECD member countries. OECD = OECD member countries. $n = 285,082$ (OECD, 224764; non-OECD, 60318). Higher item scores indicate lesser use of computers in math lessons. Item 1 = Draw graph. Item 2 = Calculation with numbers. Item 3 = Geometric

For effect size, we have reported Cohen's *d* in the last column of Table 5. Cohen's *d* can be interpreted as the standardized difference between means of the two groups. Cohen's guidelines suggest a value of .2 as small for this statistic. In Table 5, we can see that based on this criterion all reported effect sizes are small. In other words, although on average computer use in math lessons differs significantly between OECD and non-OECD students, from a practical standpoint the difference is small.

Discussion and Conclusion

In this study we examined the use of computers in math lessons for tasks such as drawing graphs, performing calculations, and data entry using a large scale sample of 15-year old students from 43 economies. Our results indicate that despite significant differences in economic, social, and cultural dimensions among surveyed countries, there is little difference in computer use in math lessons between students in OECD and non-OECD countries. Our findings have important implications.

First, we note that a large proportion of students in both OECD and non-OECD countries, in most instances exceeding two-thirds, indicated that they do not use computer in math lessons. In light of the fact that the students included in our sample are those who are about to enter practical life at the end of their compulsory schooling, this finding is somewhat disturbing. Given the ubiquitous use of computers in everyday life in today's world, and availability of computer and other ICT resources in modern schools, such low practical ICT involvement in the classroom is disappointing. The result itself is in line with prior research (such as Spiezia, 2011) and raises questions about the effectiveness of school-level policies that aim to promote computer use in education. In today's evidence-based culture where numbers are an important input in policy decisions at all levels of life, simple tasks such as entering data into a spreadsheet program (e.g. to construct a personal budget) or drawing a geometric figure (e.g. to communicate an idea to peers) are no longer confined to computer experts and subject area specialists. These are skills that everyone with 9-10 years of compulsory schooling should be familiar with. Our results suggest that the school systems in all countries represented by our sample have a long way to go before such ambition may turn into a reality.

Second, we observed that the pattern of computer use in math lessons was very similar between students in OECD countries and those in non-OECD countries. Given that OECD countries on average tend to be wealthier than their non-OECD counterparts, this is an interesting observation. In a way, it is telling us that ICT involvement in the classroom is no longer restricted to wealthy nations. This makes intuitive sense given the rapid spread of ICT, and in particular affordable computers, across the globe during the last two decades. Thus, among students who do use computer in math lessons, the pattern of use does not vary dramatically between the two groups of students. For instance we see that when it comes to performing numerical calculations by students themselves using computer in math lessons, the difference between OECD countries and non-OECD countries is only 1.8%. We have already seen that such gaps have little practical significance (at least in our sample). The very similar patterns of computer use by students in the two groups of countries could be suggestive of a closing technological gap at the high school level in mathematics. In other words, the playing field may finally be leveling. We are careful not to generalize this conclusion beyond mathematics because in other areas, particularly science, the technological gap in resources between rich and poor nations may still be large.

Although our study revealed interesting results, it has some limitations. First, we note that information on computer use in math lessons was self-reported. Although it is difficult to imagine collusion or widespread misreporting in such a large sample of students, the accuracy of our statistical results and by extension the accuracy of any conclusions based on those results remains a function of the accuracy of self-reported data. Second, we

emphasize our examination of computer use specifically in math lessons. Thus, our findings may not be generalizable to areas that are very different from mathematics, especially within the context of ICT use. Third, our findings should not be generalized to students other than those represented by our sample. This is important because many countries, among them some of the least developed in the world, did not participate in the survey. Thus, making generalizations to countries that are very different from those listed in Table 2 may result in inaccurate judgments and conclusions. Similarly, our results are based on students who are about to complete their compulsory schooling, and thus may not be relevant to students at other education levels such as college, university, middle school etc.

For future research in this area we suggest two courses of action. First, our study can be replicated with a different sample of countries, subject areas, and students, in order to expand the evidence base for computer use in formal education. Second, our method can be replicated at country level in order to identify country-specific factors of ICT use in the classroom. Given the usually significant differences in economic, social, and cultural atmosphere across countries, this set of factors is likely to differ across countries.

Statements and Declarations

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During the preparation of this article, the authors did not use ChatGPT.

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Data Availability: Not applicable.

Ethics Approval: All methods were performed in accordance with the study protocol and ethical guidelines and regulations.

Informed Consent: Not applicable.

Conflicts of Interest: The author declares no conflicts of interest.

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