Combating the Creativity Gap in the Global Era: Using Mobile Devices to Assess and Develop Critical Thinking Skills Among Palestinian Youth

Elizabeth Buckner and Paul Kim
Stanford University

Abstract

This study examines how mobile computing devices can help gauge critical thinking and creativity among Palestinian youth from varied socioeconomic backgrounds. We first developed mobile games and creative writing workshops to gauge creativity and problem solving abilities of participating students, and then gathered data from a sample of 185 Palestinian youth, aged 6-16. Our findings indicate that there is a real and concerning creativity gap among Palestinian youth that is highly correlated with factors associated with students' socioeconomic backgrounds. Basically, findings indicate that there are real differences between average creativity and performance of students at different schools, suggesting that some schools and families are preparing their children to be creative thinkers to a much greater extent than are others. While students may seem to be getting the same general grades across schools, it seems that the skills of problem-solving and creativity may be a luxury of the children of the elite. We argue that mobile technologies can be used to supplement traditional pedagogies and to promote critical thinking in schools that are under-resourced.

Introduction

Much research on globalization has pointed out that with the rapid pace of economic, social, and political change, solutions to the problems of the future may not be learned in conventional textbooks, or even online. In fact, we live in a world of rapid change, such that the problems that tomorrow's youth will face may be yet unpredicted. As such, we believe that increasingly important skills for today and tomorrow's youth are problem solving, creativity, and analytical thinking (See DeHaan, 2009; Gardner 2006; Trilling & Fadel, 2009; Wan, 2011).

The need for a major curriculum renewal is perhaps most pressing in many developing nations, which often face existential issues such as population growth, environmental degradation, migration flows, food and water shortages, civil strife, and political instability, along with longstanding issues of poverty and inequality. To confront the many rapidly changing demands these nations will face in the coming years, developing countries must enable their citizens to be creative and innovative problem solvers.

Despite the widespread recognition of the importance of innovation in the face of global problems, this study points out the fact that schools are inherently conservative institutions, and traditional teaching methods are notoriously difficult to change (Lortie 2002; Tyack and Cuban 1995). Additionally, we note that it is particularly those schools in under-resourced communities that are the least likely to stray from centrally scripted curricula, and the least likely to devote time to fostering creativity (Carnoy 1974; Fasheh 1997). Sociologists of education have long pointed out that the children of the poor are educated quite differently than those of the elite. Also, ethnographic studies have shown how pedagogical styles differ across social class, and how the poor may be receiving what critical theorists have called a "hidden curriculum" or a "a pedagogy of the oppressed," which encourages following directions and memorizing information, rather than posing and solving questions (Anyon 1980; Freire 1970).

While the subtle but pernicious effects of the "hidden curriculum" to sort youth into life paths with fewer opportunities may certainly have been true in past, the effects of contemporary globalization have potentially made the consequences of the marginalization and exclusion of the poor from the global economy and world society much more disastrous. Scholars have argued that the goal of nation-states in the contemporary era must be to incorporate their most marginalized, as the potential for social and political radicalization is high among marginalized social groups (Carnoy and Castells 2001). This concern is particularly true in the greater Middle East region where youth radicalization has flourished the rise of fundamentalist and extremist religious and political groups. The potential for radicalization is especially worrisome among youth in the West Bank, where the citizens have suffered for many decades from their own leaders' corruption as a result of the geo-politics of the Israeli-Palestinian conflict.

It is against this larger backdrop of globalization and geo-politics that we question: does it matter how students are doing in school, as measured by their grades, if they are not learning how to be creative thinkers? Or perhaps even more cynically, what will result from a national education system where children of the elite are being cordoned off in private English-instruction schools where creative thinking is encouraged, while the children of the masses are carrying out only rote memorization that will not serve them well in the future economy or society?

Our research is motivated by a concern over this potential "creativity gap" between the rich and poor, and a concern over the highly didactic and uninspiring pedagogies used in many classrooms, which are preparing neither children nor nations to meet existing and coming challenges. Yet, our research is also motivated by the conviction that mobile technology can serve as a great equalizer. In many regions of the developing world, mobile phones have spread far faster than have roads or running water, and now reach even the most rural of villages. Building off huge advances in technology in the past few decades, this study examines how mobile computing devices can promote critical thinking and problem solving in developing nations, focusing specifically on the West Bank, Palestine.

This study asks two questions: first, can we assess the severity of the critical thinking and creativity gap in the developing world and identify its correlates? And secondly, can we harness the vast potential of mobile technologies to teach critical thinking and problem solving to youth in severely under-resourced schools worldwide?

We chose the West Bank, Palestine as the site of our research because it exemplifies the challenges that many developing nations are facing. More specifically, severe income inequalities in this region provide vastly different educational opportunities to children from different backgrounds. There are high unemployment rates, environmental concerns, water supply challenges, and widespread corruption, all of which exist amidst a much larger political issue of violent conflict. Although the West Bank is geographically small, and its population totals only 2.4 million, its political and geographic challenges are immense. Additionally, prior research on the effects of conflict in the West Bank and Gaza suggest that political conflict may be interfering with Palestinian children's abilities to concentrate in school, and with their development of analytical skills (Kanagaratnam 2009; Qouta, El-Sarraj &Punamaki, 2001).

Background

Creativity and critical thinking

Creativity is notoriously difficult to define and measure. O'Rafferty et al. (2009) explain that "Creativity is regarded as one of the more enigmatic, compelling and little understood aspects of human thinking" (O'Rafferty, O'Connor, and Curtis 2009). We adopt the definition that creativity involves generating novel ideas to solve complex problems, making it an integral aspect of problem solving.

Unfortunately, despite widespread concern over the need for creativity and problem solving, many have argued that both are rare (Avery 1994; Carr 1988). Moreover, educational research suggests that formal educational settings may be particularly maladapted for promoting critical thinking. Scholars have also argued that we know little about how to teach problem solving in formal education settings, or how to ensure that skills learned in formal settings transfer to real-life problems. As Jonassen (2000) explains: "learning to solve problems is too seldom required in formal educational settings, in part, because our understanding of its processes is limited" (2000: 1).

Carr (1990) has argued that critical thinking should be inserted into all aspects of the curriculum and pedagogy. However, years of research have demonstrated that educational institutions are conservative in nature, and that most reforms tend to be superficial and piecemeal at best (House 1998). Thus, while university researchers may be quick to advance new pedagogical methods to strengthen critical thinking, seasoned teachers are much less likely to change their longstanding practices. It is hard to be too critical

of teachers in these environments; after all, educational reforms are notoriously political and quick to change, and teachers are often unable to effectively implement changes to the curricular requirements without substantial training and additional instructional time. Additionally, research has shown that even the most effective reforms have essentially been curricular add-ons, as opposed to substantive changes in the structure of schooling (House 1998; Lortie 2002). All of these factors make us skeptical that traditional classroom practices and pedagogies will be able to effectively deal with the challenges of globalization. Indeed, while traditional schools are quite good at processing large batches of students through routinized learning, they are rarely catalysts for innovation.

In response to traditional educational institutions' intertia, our research looks to the potential of mobile devices to offer challenging and personalized learning environments to students working individually or in small groups. In recent decades, there has been a rapid proliferation of mobile devices around the world, and scholars are increasingly looking to mobile technology for its educational potential (Cabrero 2002; Chinnery 2006; Joseph, Binsted, and Suthers 2005; Kadyte 2004; Kiernan and Aizawa 2004; Levy and Kennedy 2005; Norbrook, English, and Scott 2003; Ogata and Yano 2004; Paredes, Ogata, Saito, Yin, Yno, Oishi, and Ueda 2005; Thornton and Houser 2005). Moreover, recent advances in information and communication technology (ICT) have dramatically increased the potential of mobile devices as educational tools. Specifically, increases in processing power, memory, and connectivity for mobile handheld devices have made them more interactive and media-rich than ever before (Pea and Maldonado 2006). For example, mobile devices can now store a significant amount of information, including a wide variety of targeted curricular materials, games, and critical thinking exercises.

Mobile devices also have many practical advantages over traditional desktop-based computers in developing countries. Three major advantages are that they require substantially less infrastructure and electricity and are capable of reaching even the most isolated audiences (Attewell 2005; Kim 2009). Research has also shown that mobile learning devices have the potential to widen access and supplement education in remote and underserved areas of the world (Zurita and Nussbaum 2004). Many have noted that this makes them more apt tools for large-scale impact (Kim, Miranda, and Olaciregui 2008). These factors all suggest that mobile devices could be effective in supplementing education particularly in a community with a poor educational infrastructure (Kim, 2010).

Executive functions

As an initial point of exploration, we chose to limit our definition of critical thinking to analytical thought, as measured by executive functions (EF). Executive functions are defined as goal-directed behavior including strategic planning, impulse control, organized search, and flexibility of thought and action. This type of behavior is governed by the frontal lobe of the brain and, although not the same as intelligence, is associated with the ability to perform many of the skills necessary to succeed in school, as well as the skills needed to solve problems (See Best, Miller, & Jones, 2009).

Our reasoning for focusing narrowly on executive functions was both substantive and logistical. First, we wanted to capitalize on the substantial existing literature in psychology and education by relying on validated tests of critical thinking and problem solving abilities. In addition, we were interested in conducting a study that could be carried out in a reasonable time frame with a highly replicable method involving low-cost mobile computing devices. Consequently, we chose to focus our study on executive

functions as measures of students' abilities to think both analytically and creatively to solve concrete tasks. For example, Kanagaratnam (2009) explains that, "cognitive flexibility is considered as the core feature of intact EF." Further, Kanagaratnam explains that intact EF functioning involves the integration of information, mental processing, and the "sub-skills necessary for purposeful, goal-directed activity" (Burgess, Alderman, Evans, Emslie, and Wilson 1998; Kanagaratnam and Asbjornsen 2007).

Education in the Palestinian West Bank

This research study was conducted in the West Bank, Palestine. Palestine was chosen as the research site because it exemplifies many challenges found throughout the developing world, including conflict, inequality, poor educational resources, and didactic pedagogies. Moreover, we believe that due to vast income inequalities and the unstable political situation, the West Bank is one of many regions in the world facing a "creativity gap," whereby the rich and poor receive drastically different types of educational preparation for the future.

Substantial prior research suggests that education in Palestinian Territories faces severe problems, as many Palestinian students are constantly exposed to the effects of entrenched political conflict. Growing up amidst violence poses particular risks for young people's social and emotional development. As the victims and witnesses of violence, adolescents in the West Bank and Gaza suffer long-term psychological damage from constant exposure to violence. In fact, a 2004 survey of 2100 Palestinian youth aged 14-17 found that 99% of surveyed youth had experienced exposure to violence. Growing up amidst violence also threatens young people's educational achievement. Nearly 60% of youth exposed to violence in the West Bank and Gaza report having difficulty functioning in school as a result of the psychological trauma of conflicts (Abdeen, Qasrawi et al., 2008). Not surprisingly, students' academic achievement is woefully low (UNICEF 2007).

Additionally, prior research has found that not only do youth in Palestine suffer from psychological trauma and post-traumatic stress disorder (PTSD), but that these may be causing executive function deficits. Encouragingly, research does suggest that intact executive functions and cognitive flexibility may help students overcome the negative effects of living amidst trauma. Kanagaratnam (2007) explains that "a flexible information processing style, or in other words creative problem-solving, has been found to have a moderating effect on the negative long-term consequences of traumatic events on Palestinian children exposed to political violence during the Intifada" (Kanagaratnam and Asbjornsen 2007; Qouta, El-Sarraj, and Punamaki 2001).

Figure 1: Map of the West Bank

Source: CIA Factbook (2009)

Methodology

The data comes from a convenience sample of students gathered through contacts with Ministry officials and NGOs. The data was collected in March 2010 from 185 students, ranging in age from 8-15. Our sample was not designed to be representative, but rather constituted the preliminary step of an action-research design targeted to serve disadvantaged populations (See Kim, 2009).

Because we were interested in assessing the existence of a "creativity gap," we sampled for range, seeking students from diverse backgrounds. Weiss (1995) argues that such a method is appropriate for a small-scale focused study. In total, we visited seven institutions, including: public and private schools, after-school programs run by the UN Relief and Works Agency for Palestine Refugees (UNRWA), private English language centers, and non-governmental organizations (NGOs).

Students came from a variety of backgrounds, including students studying in prestigious bilingual private schools in Ramallah, students in rural villages, and students cut off from the rest of Palestine by the separation wall between Israel and Palestine. In total, we visited seven different schools and groups (three in Ramallah, two in Nablus, one in Qalqiliya, and one in a small village called Al-Media). Students in the isolated schools in the small villages and Qalqiliya did not have access to home computers, and electricity was often restricted to two hours a day. Given the wide diversity of students and schools we visited, we are confident that we captured the experiences and stories from a wide range of Palestinian students.

We collected three types of complimentary data: 1) short surveys from students on their age, school performance and home background; 2) writing samples from students on a topic of their choice; and 3) two types of executive function tests, which were pre-loaded onto mobile devices.

The mobile devices used in this study were TeacherMate Handheld Computer Systems (See Figure 2). This mobile device consists of a color screen (11 cm by 7.5 cm), four direction arrow buttons, three control buttons, one execution button, a built-in microphone, an integrated speaker, and a headphone output jack. A headphone set is included for individual use. The devices use a Linux operating system, and programs can be developed in open-source Flash (GNASH), allowing open-access and easy development of further interactive learning contents with little knowledge of Flash programming. The manufacturing cost of a single device is $50 USD. The devices use the same ARM processors (i.e., Advanced 32-bit RSIC, reduced instruction set computer, Machine) that are used in conventional smartphones. We used a built-in USB communication port to upload learning game contents and download student performance data. We loaded a number of critical math and literacy activities onto the devices, which were used to familiarize the participants with the devices before completing the executive function exercises.

Figure 2: Mobile computing device

In addition, we designed two EF games specifically for the mobile devices, which we called "Disc Stacking" (Figure 2) and "Card Matching," (Figure 3) which adopted the logic of the Wisconsin Card Sorting Task and the Tower of London test, respectively, which are previously validated EF tests. The Tower of London test is a widely used psychological test (See Phillips et al., 1999) used in applied clinical neuropsychology for the assessment of executive functioning, specifically to test students' ability to plan action and solve concrete problems. In our version, the "Disc Stacking" game presents the child with an image of three stacks of multi-colored discs, which is labeled the "target" image. The child is also presented with a second image of the same number of multi-colored discs that are stacked in a different order and pattern, and is asked to rearrange the second set of discs to replicate the target image exactly. In carrying out this task, the student must a) solve a concrete cognitive task (i.e., solve an explicit problem) and b) make future execution plans. Specifically, the child must rearrange the discs so that the required discs are available when needed, and not at the bottom of a stack of other discs.

The Wisconsin Card Sorting Test (WCST) is a psychological test of "set-shifting," written by David Grant and Esta Berg (See Grant & Berg, 1948). In our version of this executive function test, which we called "Card Matching," a card is displayed with a certain number of colored shapes – for example, one blue circle or two green cylinders. As Figure 3 shows, below this "goal" card are four possible choices that serve as hypothetical matches for this top card. The students must figure out the "matching rule" – either the cards will be matched on color, shape or number. After each selection, students are provided feedback indicating whether their answer was correct or not. Thus, if the student correctly figures out that the "matching rule" is to match on color, then for a string of cards, he or she should be able to get all correct answers by matching on color. However, at irregular intervals, the "matching rule" will change, and students will have to adapt to the new rule. Thus, the number of correct responses out of a set of 32 responses indicates how fast the student was at adapting to the new information.

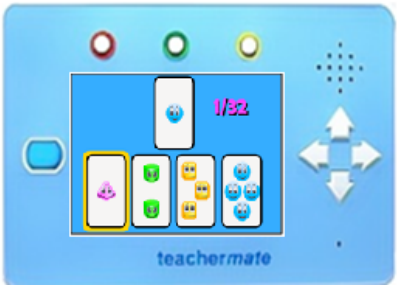

Figure 3: Card Matching Game

Our data collection method was based on the principles of inquiry-based learning, and followed a procedure used in prior studies in various countries, including India, Mexico, El Salvador, and Rwanda. We first asked students to partner in small groups and gave each group a mobile device. We did not offer any instructions on how to use the mobile devices. Instead, we asked students to figure out what the devices were and to explain them to us. This approach encourages students to figure out what to do on their own, which accords with the principles of child-centered pedagogy (i.e., self-regulative and creative problem solving), in contrast to the didactic method that is prominent in many Palestinian schools. We found that many students were able to quickly manipulate the devices and begin playing with the devices on their own.

By trusting students' creative curiosity, and giving them as much time as needed to explore the devices, we found that in nearly all classrooms, students were able to turn on the devices and begin playing games after 15-20 minutes when working in small teams of two or three. Moreover, although we gave minimal instructions concerning how to play the warm-up math and literacy games, students were nonetheless incredibly successful at discovering the rules as they went along. When confusion arose over the instructions of a specific game, we asked a student who had already successfully figured out the instructions to explain it to the rest of the class (i.e., peer group teaching to minimize teacher's involvement).

After each student had a basic understanding of the devices and how to manipulate them in small groups, we gave each student a mobile device and asked them to complete the two executive function exercises according to the specific instructions we gave (See Figure 3 Left). A unique identification number matched each student with a device, which allowed us to export student performance data and link it to survey and writing data for further analysis. Exported performance data included outcome measures as well as time stamps for every button pressed.

As part of our workshop with students, we modeled short, inspiring stories (i.e., collected from children in other countries) to the Palestine students, and asked them to write a story from their imagination or real life that they would like to share with other children around the world. Each writing sample was then coded on a scale of 1-5 across four dimensions: a) length, b) grammar, c) structure, and d) creativity (See Appendix A). In collaboration, a bilingual researcher read and coded all the writing samples in both English and Arabic in order to ensure internal reliability across writing pieces. As is shown in Table 1 below, the mean for all four variables is approximately 3, which is what would be expected given a roughly normal distribution. It should be noted that we also implemented a mobile story maker application in several classrooms (Shown in Figure 3 Right) to help students generate creative stories, but this took much more time than initially expected; the mobile story maker activity was not conducted at all schools and the data collected from this particular activity was not included in the analysis for this study. Interestingly, this particular mobile activity turned out to require high-level literacy and creative thinking skills, which were not equally present in all schools we visited (i.e., only those with high-level literacy and EF skills successfully generated digital stories with the mobile devices).

Figure 3. Left - Students working on executive function games. Right - Mobile story maker application

Finally, we collected survey data on a range of variables, including students' ages, grade level, interest in the mobile devices, access to mobile phones, their self-reported GPA as well as a self-assessment of their performance in school, on a scale of 1-7. We also asked students to indicate their interest in the devices on a scale of 1-7, and to mention which aspects of the devices they did or did not like. These surveys were administered at the end of every workshop with all students, and correlations are shown in Table 3.

Data and Variables

Table 1 below presents the descriptive statistics of each of the variables used in our analysis, which were gathered either directly from student surveys or from students' performance in playing with the devices. We can see that 53% of our sample was from urban schools, while the remaining was from rural areas. We worked with students in grades 1-10, and aged 6-16.

Table 1: Descriptive Variables

	Source	**Mean**	**SD**	**Min**	**Max**	**N**
Age	Student Survey	10.75	2.09	6	16	181
Grade in School	Student Survey	5	2	1	10	184
GPA	Student Survey	86.20	13.92	22	100	182
Urban	Institutional Data	0.53	0.50	0	1	193
Private School	Institutional Data	0.27	0.44	0	1	193
Interest in Devices	Student Survey	6.44	1.15	1	7	189
English	Writing Samples	0.61	0.49	0	1	121
Length of Writing	Writing Samples	2.75	1.47	1	5	121
Grammar in Writing	Writing Samples	3.13	1.17	1	5	121
Structure of Writing Sample	Writing Samples	2.88	1.11	1	5	121
Creativity in Writing Sample	Writing Samples	3.02	1.07	1	5	121
Time to Complete Card Sorting	Device Data	133.46	38.78	58	267	121
Card Correct Responses	Device Data	50.96	15.06	19	77	121
Disc Stacking Completion Time	Device Data	841.79	425.44	280	2021	121
Family or Self Owns Cell Phone	Device Data	0.60	0.49	0	1	191

We also examined correlations between our data. As Table 2 below indicates, age and grade level are strongly correlated, as we would expect, with a correlation of (0.80). However, they are not perfectly

correlated, which is most likely related to the high level of grade repetition in Palestine. We also found that on average, GPA exhibits a weak but positive correlated to age (0.19). This may simply be the result of our non-random sample, as some of the older students (12+) in our sample are those participating in a structured language-learning program, which targets academically gifted, but economically disadvantaged students.

There are a number of other correlations worth pointing out in Table 2. For example, we find that the verbal index (a composite created from by averaging grammar, length and structure from writing samples) is not highly correlated with any variable except for GPA (0.36). It makes sense that students with higher grades in school would be expected to have generally better linguistic skills; however, it does seem surprising that GPA was not correlated positively to students' self-reported assessment of their performance in school. In addition, we note that students' interest in the devices goes down markedly as their ages go up. This also makes sense, as the devices we used were not particularly technologically advanced, and could not compete with the capacities of the latest smart phones available. Additionally, many of the games and stories we translated were aimed at upper elementary-age students.

Table 2: Survey Data Correlations

	Age	**Grade**	**GPA**	**Self-Assessment**	**Interest in Devices**
Age	1				
Grade	0.8994	1			
GPA	0.1945	0.2708	1		
Self-Assessment	-0.1194	-0.1664	0.1365	1	
Interest in Devices	-0.3327	-0.4262	-0.0927	0.1487	1
Verbal Index	-0.0498	-0.0387	0.3626	-0.0902	-0.0389

Outcomes

The outcomes of interest to us are both qualitative and quantitative measures of academic performance, namely: literacy skills (as garnered through a rubric-based rating of student writing samples), executive functions (as measured from small psychological exercises conducted on mobile devices), and self-reported school performance. The study controls for differences in students' school environment and whether the school was private or public.

Writing samples constituted a source of data on students' creativity; each writing sample was read in its entirety and coded on a scale from 1-5 based on a rubric of how well it met criteria for length, grammar, structure and creativity. As shown in Table 3 below, the students who wrote in English (i.e., students at private schools or at a private language center) tended to write pieces that were longer but that contained more grammatical errors. In contrast, creativity is slightly positively correlated with writing in English, and quite strongly correlated with longer pieces, more grammatical prose and the ability to write a well-structured essay. In general, we get a clear picture that students' linguistic skills tend to be bundled together as part of a general linguistic competency, and that those students in English schools, which are private and urban, tend to have higher linguistic competencies overall. These correlations accord to substantial research in language learning and sociology, which suggests language skills tend to be interrelated, and that those students from the upper classes tend to have better developed language and literacy skills generally.

Table 3: Writing Sample Correlations

	English	Length	Grammar	Structure
English	1			
Length	0.6652	1		
Grammar	-0.0989	-0.005	1	
Structure	0.0545	0.355	0.3004	1
Creativity	0.1939	0.3972	0.4046	0.7391

As a result, we developed a composite measure called "verbal fluency index," which was created by equally weighting length, grammar and structure into one variable. These three variables are positively correlated with one another, and combining them into one measure allowed us to decrease our degrees of freedom, and limit co-linearity.

In terms of our executive function outcomes, we measured the time it took for students to complete the card-sorting task, the Disc Stacking task, and the number of correct responses the students had when playing the card-sorting task. The correlations between the two are shown below:

Table 4: Correlations among Executive Function Outcomes

	Card Time to Completion	Card Correct Responses
Card Time to Completion	1	
Card Correct Responses	-0.4372	1
London Tower Time to Completion	0.3131	-0.3083

As is clear from Table 4, there is a non-negligible correlation (0.31) in the time-to-completion of both activities, suggesting that many of the students who excel at one task also excel at the other. However, there is a significant negative correlation between the students' completion time of the card-sorting activities and their number of correct responses. This suggests that many students simply sorted cards, without switching mental frames. We are more interested in the number of card-sorting activities students correctly answered, because a correct answer indicates an understanding of the game and an ability to think and respond dynamically.

Analysis and Discussion

In our data analysis, we pursued two strategies. We performed one- and two-way ANOVA analyses to examine how means might vary across students and schools. We then used multivariate regression to examine correlations between our outcomes of creativity and critical thinking, and the independent variables of individual attributes.

First, we were interested in assessing the severity of the "creativity gap," and determining the extent to which student and family attributes are correlated with the ability to think creatively. To examine whether there are significant differences in mean level of creativity across schools, we conducted a one-way ANOVA, as shown below.

Table 5: ANOVA Examining Creativity Across Schools

Source	Sum of Squares	Degrees of Freedom	Mean Square	F-Statistics	Prob > F
Between groups	22.057	3	7.35	7.49	0.0001
Within groups	114.87	117	0.98		
Total	136.93	120	1.141		

The findings above suggest that there is a strong between-group difference in average score; we know from descriptive variables that schools with students from higher SES backgrounds have higher mean levels of creativity. This means that schools vary drastically in the extent to which their students are creative thinkers, either because of differences in home environment or because of the way that schools are preparing students, or some both. Our site visits confirmed that not only is there a huge need for the development of creative and critical thinking in Palestinian schools, but also that creativity is not equally distributed across our sample of students, with richer students and those in English-speaking schools more creative on average. In site observations, we found that while many students figured out things on their own without teacher intervention, in classes where teachers were attempting to help them figure out how to engage in the activities, students quickly developed a tendency to rely on their teacher's help. When they were given partial help, some of the students easily grew frustrated or dependent on their teachers' help. In short, we believe that inquiry-based methods are a more effective pedagogical approach for getting children to become active agents of their own learning.

We are also concerned with the broader implications of what this gap in creativity might mean for students on the wrong end of the creativity continuum. Much as scholars of previous decades pointed to the existence of a "digital divide" and its implications, we are concerned about what a growing "creativity gap" might mean for the poorest and most marginalized in the developing world. We also carried out a two-way ANOVA, to examine whether there are significant differences in creativity across schools after accounting for differences in student GPAs. The results are shown in Table 6 below.

Table 6: Two Way Anova: Creativity and GPA

Source	Partial SS	df	MS	F	Prob > F
Model	24.61	6	4.10	4.16	0.0008
GPA	2.55	3	0.85	0.86	0.46
School	10.56	3	3.52	3.57	0.016
Residual	112.31	114	0.99		
Total	136.93	120	1.141		

The model above clearly indicates that there is a strong school effect – students in private, English-speaking schools are creative thinkers to a much greater extent than are those in rural or public schools. Interestingly, we find that there is not a strong effect of self-reported GPA on creativity – in other words,

while we do not find strong variation across schools in grades, we do find that separate from grades, some schools are home to more creative students than others. This suggests that while students may all be getting the same general grades across schools, the quality and content of their education is not the same, and that practice in the skills of problem-solving and creativity may be a luxury of the children of the elite. These findings accord with many previous studies in the sociology of education, which find that pedagogical styles differ across social class, and that the poor may be receiving what critical theorists have called a "hidden curriculum."

Although we suspected there would be a creativity gap, we are also interested in what factors predict this gap. We examined a series of uni- and multi-variate models to examine the association between school and student characteristics and creativity. Our basic model (Model 1) investigates the effect of age, while Model 2 adds in the role of student-reported GPA. Models 3 and 4 add in two school variables, whether the student was in an English-speaking school or a private school, both of which are highly correlated with socioeconomic status, and are investigated separately because of the high correlation between the two. Lastly, Model 5 investigates the effect of verbal index, as gathered from writing samples.

It is clear from Table 7 below, that neither age nor school GPA was strongly associated with increases in creativity. Although GPA does appear to be correlated with creativity initially, the magnitude of the association is very small. In contrast, we can see that being in a private school, and having a high score on the "verbal index" measure are both strongly positively correlated with higher creativity ratings. The magnitude of both variables is greater than 0.85, which is nearly one full standard deviation in the creativity variable.

Table 7: Correlates of Creativity in Writing Samples

	Model 1		**Model 2**		**Model 3**		**Model 4**		**Model 5**	
Age	0.01		-0.02		-0.03		0.09		-0.06	
	0.04		0.04		0.05		0.05		0.04	
GPA			0.02	*	0.02	~	0.01		0.00	
			0.01		0.01		0.01		0.01	
English					0.26					
					0.26					
Private							0.85	**		
							0.27			
Verbal Index									0.92	**
									0.28	
Constant	2.86	***	1.26		1.73	~	1.17		2.98	**
	0.50		0.81		0.94		0.78		0.94	
N	115.00		111.00		111.00		111.00		111.00	
R2	-0.01		0.04		0.04		0.11		0.12	

In addition, examining the correlates of creative thinking underscores the fact that creativity in writing does not seem to be a "learned" skill, as it is neither correlated with age, nor self-reported academic performance. This interesting phenomenon leads to the second part of our data analysis, which examined whether mobile devices could be used to assess and promote critical thinking.

Can Mobile Devices Be Used to Promote Critical Thinking?

The second step in our analysis was to understand the correlates of critical problem solving, as measured by executive function psychological games. Our goal in this introductory stage was to show that mobile devices could reliably measure critical thinking skills, so that future research can develop more games to develop these skills among students.

Table 8 below shows the factors associated with time-to-completion of the Disc Matching game; our models are the same as those outlined above. As the results show, age is strongly negatively correlated with time-to-completion, suggesting that older students are better able to carry out the activities. This is expected, considering their abilities to manipulate the devices, as well as their greater levels of psychological development. We also find that in our initial model, an increase in GPA is negatively correlated with time-to-completion. However, after controlling for other factors, including whether the student is at a private school or wrote in English, there is no significant effect of GPA on time-to-completion, implying that student reported GPA is not a significant predictor of the time students' required to complete the EF matching activity.

With respect to the relationship between creativity and time-to-completion, we find that while the verbal index is negatively associated with time-to-completion – meaning students with better verbal abilities are faster (which may be both an indicator of social class, intelligence and educational quality). However, this association is not statistically significant. Increases in creativity scores also reduces time-to-completion, and this association was found to be statistically significant even after controlling for many important student-level attributes, including age, GPA, and whether the student was at a private school.

Table 8: Factors Affecting Disc Stacking Completion Time

	Model 1		**Model 2**		**Model 3**		**Model 4**		**Model 5**	
Age	-73.44	***	-59.11	***	-87.37	**	-80.58	**	-77.30	**
	16.10		16.23		25.94		26.50		26.02	
GPA	-6.49	*	-0.68		0.70		0.98		1.32	
	3.17		3.61		3.73		3.73		3.68	
English			-278.90	**	-178.31		-187.79		-204.40	~
			92.23		116.82		116.86		115.78	
Private					-177.95		-106.00		-98.69	
					127.75		140.97		131.63	
Verbal Index							-60.98			
							50.98			
Creativity									-72.71	*
									35.37	
Constant	2256.41	***	1745.78	***	1948.75	***	2004.21	***	1983.87	***
	299.58		334.61		363.62		365.84		358.62	
N	111		111		111		111		111	
R2	0.21		0.27		0.27		0.28		0.29	

These results give support to the idea that both our assessment of student creativity, as coded from independent writing samples, and students' ability at performing executive functions requiring "mental flexibility" are mutually reinforcing. Moreover, we found that the magnitudes of difference were quite similar – a one-year increase in age results in decrease in time-to-completion of the Disc Stacking activity

that is approximately equal to a one-unit increase in creativity, which is roughly equal to one standard deviation increase in creativity. The R-squared value also suggests that Model 5 is the best fit.

Table 9 investigates the role of factors affecting the time-to-completion in the card-matching EF exercise, using the same five models discussed above. We find similar results in terms of the role of creativity in predicting time-to-completion. While the card-sorting activity was limited to sets of 32 cards, and therefore, took substantially less time over all (approximately 3-4 minutes for each round), creativity was a statistically significant predictor of decreased time to completion. In fact, we find that while age did not have a significant impact on time-to-completion, being in an English-speaking classroom, which is correlated with wealth and age, may wipe out the independent effects of age and GPA. In the case of card sorting time-to-completion, the verbal index was also marginally statistically significant, and the magnitude of its effect seems similar to that of the creativity variable.

Table 9: Factors Affecting Card-Matching Time-to-Completion

	Model 1		**Model 2**			**Model 3**		**Model 4**		**Model 5**	
Age	-3.64	*	-2.22			-4.64	~	-3.71		-3.52	
	1.52		1.53			2.44		2.48		2.43	
GPA	-0.63	*	-0.05			0.06		0.10		0.13	
	0.30		0.34			0.35		0.35		0.34	
English			-27.52	**		-18.92	~	-20.22	~	-21.81	*
			8.67			11.00		10.92		10.82	
Private						-15.21		-5.36		-6.43	
						12.03		13.18		12.30	
Verbal Index								-8.35	~		
								4.76			
Creativity										-8.06	*
										3.31	
Constant	230.58	***	180.20	**	*	197.5506	***	205.15	***	201.44	***
	28.28		31.47			34.25		34.19		33.51	
N	111		111			111		111		111	
R2	0.09		0.16			0.17		0.18		0.21	

However, because the outcome correlations (See Table 4) suggest that correct responses and time to completion are negatively correlated, we also were interested in examining factors affecting correct responses, and the ratio of correct responses to time played on activities. The results are shown in Table 10 and Table 11.

Table 10 suggests that both age and GPA are initially strong predictors of correct responses, but once various student-attributes are added in as controls, GPA drops out and attending a private school becomes a significant predictor of correct responses. We suspect that this is because students at private schools tend to be from the upper classes, and may be exposed to significantly different pedagogies than students at public schools. Moreover, we find that both having strong verbal skills, and creativity in writing pieces are strong positive predicators of correct responses to the card-sorting activity, which requires the ability to "change mental sets" and adapt to new conditions to correctly match cards. While the R-squared value is the same in Model 4 and Model 5 in Table 10, in Table 11, we examine the ratio of correct responses to

time-to-completion, and find that Model 4, with only the Verbal Index is actually a better predictor of correct responses. In short, our multivariate analyses suggests that creativity in writing is strongly correlated with analytical problem solving, even after controlling for age of students and their home and school environment, in the form of school type and family resources, as represented by whether the student is in a private or public school. We believe that the fact that creativity is a generally robust predictor of ability to solve executive function activities suggests that analytical games such as these can be used both for measuring and developing students' analytical flexibility and problem solving.

Table 10: Factors Affecting Number of Card-Matching Correct Responses

	Model 1		Model 2		Model 3		Model 4		Model 5	
Age	0.02	**	0.02	*	0.05	***	0.04	**	0.04	***
	0.01		0.01		0.01		0.01		0.01	
GPA	0.00	*	0.00		0.00		0.00		0.00	
	0.00		0.00		0.00		0.00		0.00	
English			0.14	**	0.02		0.04		0.04	
			0.04		0.05		0.05		0.05	
Private					0.20	**	0.10		0.13	*
					0.06		0.06		0.06	
Verbal Index							0.08	***		
							0.02			
Creativity									0.06	***
									0.02	
Constant	-0.18		0.07		-0.16		-0.24		-0.19	
	0.15		0.16		0.17		0.16		0.16	
N	111		111		111		111		111	
R2	0.14		0.20		0.27		0.35		0.35	

Table 11: Correlates of Card-Matching Correct Responses-to-Time Ratio

	Model 1		**Model 2**		**Model 3**		**Model 4**		**Model 5**	
Age	1.64	**	1.16	~	4.17	***	3.31	***	3.50	***
	0.61		0.62		0.92		0.87		0.88	
GPA	0.23	~	0.04		-0.11		-0.15		-0.15	
	0.12		0.14		0.13		0.12		0.12	
English			9.36	**	-1.34		-0.14		0.40	
			3.51		4.17		3.82		3.92	
Private					18.92	***	9.81	*	13.64	**
					4.56		4.61		4.45	
Verbal Index							7.71	***		
							1.67			
Creativity									4.84	***
									1.20	
Constant	11.32		28.45	*	6.88		-0.14		4.54	
	11.31		12.75		12.97		11.97		12.13	
N	111		111		111		111		111	
R2	0.10		0.15		0.26		0.38		0.36	

The sum of our multivariate analyses suggests that creativity in writing is strongly correlated with analytical problem solving, even after controlling for age of students and home and school environment, in the form of school type and family resources, as represented by whether the student is in a private or public school. We believe that the fact that creativity is a generally robust predictor of ability to solve executive function activities suggests that analytical games such as these can be used both as proxies for measuring and developing students' analytical flexibility and problem solving.

Conclusion

Our findings suggest that there is a strong school effect – some schools and families are preparing their children to be creative thinkers to a much greater extent than are others. While students may all be getting the same general grades across schools (i.e., viewed at the surface level), the real quality and content of their education is most likely not the same, and that practice in the skills of problem-solving and creativity may be primarily developed in private, English-speaking schools. These findings accord with many previous studies in the sociology of education, which find that pedagogical styles differ across social class, and that the poor may be receiving what critical theorists have called a "hidden curriculum" or a "a pedagogy of the oppressed" that encourages following simple directions and memorizing plain information, rather than posing and solving questions

Amidst difficult educational conditions, educators and policymakers must be creative in how they meet the educational needs of children. Moreover, in the era of contemporary globalization, educators must think broadly about what children's current and future needs may be, recognizing that if they are only responding to today's problems, then they may not truly be preparing their youth for the problems of tomorrow.

Our study has demonstrated that there is a real, and concerning "creativity gap" that is highly correlated with factors associated with students' family backgrounds. We have also demonstrated that executive function games are reliably correlated with other measures of creativity, and can be used in under-resourced schools in the developing world to measure and assess critical thinking skills. We believe that future research must investigate how mobile devices can actually be used to develop student creativity or creative thinking in under-developed regions in order to combat this "creativity gap" that we have identified.

The numerous affordances of mobile learning technology (e.g., affordability, low-cost, low-electricity consumption, rapid deployment possibility, large storage and computing power, minimum-maintenance cost, easy-data gathering mechanism, etc.) hold the potential for truly creative solutions to many of traditional educational and social woes, as mobile devices have the potential to benefit children by helping them become more creative and flexible problem-solvers in and out of the classroom. Specifically, mobile technologies can bring learning activities to students where access to school is limited or even impossible as a result of violence, political conflict, a lack of transportation, or a lack of resources. We believe that mobile technologies can be used (i.e., as versatile learning and assessment resources) to supplement traditional chalk-and-talk methods in order to promote critical thinking in under-resourced schools reliant on traditional pedagogies. Future research must conduct analyses in similar contexts to explore whether, and how, mobile devices can actually be used to *improve* critical thinking and problem solving skills, as opposed to simply assessing current student grades.

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Appendix A

Writing Sample Rubric

Rating	**1**	**2**	**3**	**4**	**5**
Length	1 sentence – 1 paragraph	1 paragraph – ½ page	½ page – 1 page	1 page – 1.5 pages	1.5 pages +
Grammar	10+ grammar mistakes; spelling mistakes common	Worse than average; 7-10 grammar mistakes; some spelling mistakes	Average grammar and spelling; 4-6 grammar mistakes	Better than average; 2-4 grammar mistakes	Very good grammar; 0-2 grammar and spelling mistakes
Structure	No narrative; random writing sample	Sequence of events exists, but is hard to follow; significant jumps	Clear narrative, but some events not relevant or in logical order	Student presents information in logical sequence which reader can follow.	Information in logical, and interesting sequence which reader can follow.
Creativity	Not imaginative or descriptive; does not capture reader's attention	Below average; sample is repetitive, o unimaginative; does not hold reader's attention	Average; sample holds readers attention, but lacks imaginative or descriptive details	Better than average; sample captures reader's attention with plot or description details	The story captures readers' attention, and is highly imaginative, or descriptive