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Global prevalence of sleep deprivation in students and heavy media use

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Abstract The latest two international educational assessments found global prevalence of sleep deprivation in students, consistent with what has been reported in sleep research. However, despite the fundamental role of adequate sleep in cognitive and social functioning, this important issue has been largely overlooked by educational researchers. Drawing upon evidence from sleep research, literature on the heavy media use by children and adolescents, and data from web analytics on youth-oriented game sites and mobile analytics on youth-oriented game apps, we argue that heavy media use, particularly digital game play, may be an important contributor to sleep deprivation in students. Therefore, educational researchers, policy makers, teachers, and parents should pay greater attention to student sleep and develop programs and interventions to improve both quality and quantity of student sleep.

Keywords Sleep deprivation · Media use · Game play · Academic performance · School-aged youth

1 Introduction

While it seems obvious to state that body and mind are interconnected and healthy sleep is essential for one to concentrate, think, and learn, educational researchers and policy makers rarely paid attention to student sleep. Meanwhile, technology use has become an integral part of youth's daily life and this use is likely to produce both positive and negative impacts. However, existing educational technology research mainly focused on exploring affordances of technology for educational purposes as well as attitudes of key stakeholders in education (e.g., teachers, students) towards

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technology (Hsu et al. 2013; Tamim et al. 2011). Although these studies are undoubtedly critical, few have examined the negative impact of technology use on students, particularly on their sleep.

The purpose of this article was to draw upon evidence from multiple disciplines to establish three arguments: 1) sleep deprivation in students is globally prevalent; 2) sleep deprivation, while having serious consequences on learning and well-being, has largely been overlooked by educational researchers; and 3) heavy media use may be an important contributor to sleep deprivation in students. To make the argument that sleep deprivation in students is globally prevalent, we drew upon evidence from two recent international educational assessments and health and sleep research. We then reviewed over 23,000 articles published by 30 major educational journals from 2000 to 2014 to show that little attention has been paid to student sleep in the educational research community. Finally, we drew upon evidence from multiple sources to argue that heavy media use, particularly digital game play, may play an important role in students' sleep deprivation. We conclude this article with recommendations for future research and practice.

2 Evidence in TIMSS and PIRLS 2011

The latest results of the Trends in International Mathematics and Science Study (TIMSS) and the Progress in International Reading Literacy Study (PIRLS) in 2011 prompted many countries to reflect on their student achievement in a global context (Mullis et al. 2012a; Martin et al. 2012; Mullis et al. 2012b). TIMSS is an international comparative study conducted every 4 years since 1995, which assesses science and mathematics knowledge and skills at grades 4 and 8. In 2011, over 600,000 fourth grade and eighth grade students from 63 countries participated in TIMSS. PIRLS, conducted every 5 years since 2001, is an international assessment that measures fourth grade reading achievement. In 2011, about 325,000 fourth grade students from 49 countries participated in PIRLS.

One important finding in TIMSS and PIRLS 2011 has been largely ignored by educational researchers and policy makers, however, as scholars focused their attention mainly on comparisons of student achievement in Asian and Western countries (Biddle 2012; Zhao 2012). Little attention was paid to the global prevalence of sleep deprivation in students, as shown in TIMSS and PIRLS 2011. In these two international assessments, researchers asked teachers to what extent they believed that their teaching was constrained by students who lacked sleep. The specific question related to student sleepiness in the teacher questionnaire was: "In your view, to what extent do the following limit how you teach this class?" One of the items under this question was "Students suffering from not enough sleep." The response options included "Not applicable," "Not at all," "Some," and "A lot."

The results showed that sleep deprivation in students is globally prevalent based on teachers' self-report (Mullis et al. 2012a; Martin et al. 2012; Mullis et al. 2012b). On average, about half of fourth grade students who participated in TIMSS 2011 were in mathematics (47 %) and science (46 %) classrooms where teaching was constrained to the degree of "some" or "a lot" thanks to sleepy students. The same was true for reading instruction for 49 % of fourth grade students who participated in PIRLS 2011.

In addition, mathematics instruction was limited by lack of sleep for 57 % of eighth grade students, as was science instruction for 58 %. Table 1 presents the top 10 countries in which teachers reported the highest rates of student sleepiness. In particular, U.S. fourth grade students had the highest percentage of sleepiness in both science and mathematics classrooms among all the countries in TIMSS 2011, and the third highest in PIRLS 2011. U.S. eighth grade students had the highest percentage of sleepiness in science classrooms and the third highest in mathematics.

It should be noted that the student sleepiness data in the TIMSS and PIRLS 2011 were based on teachers' perceptions, rather than systematic measurement of student behaviors in classrooms. Thus, it is important to verify the TIMSS and PIRLS 2011 findings with evidence in health and sleep research.

3 Evidence in health and sleep research

The global prevalence of sleep deficit in students reported in TIMSS and PIRLS 2011 is consistent with sleep research. Gradisar et al. (2011) reviewed 41 studies on adolescent sleep published between 1999 and 2010 and found that insufficient sleep time on school nights and daytime sleepiness were common in students worldwide. For example, Gibson et al. (2006) found that sleepiness was serious in Canadian adolescents based on a sample of 3,235 students, as 58–68 % of students reported that they were really sleepy in the morning. In addition, a large-scale Brazil study of 11,557 high school students (Hoefelmann et al. 2013) showed that the prevalence of poor sleep

Table 1 Top 10 countries by percentage of students whose lacked sleep according to their teachers

	4th grade			8th grade	
	Mathematics	Science	Reading	Mathematics	Science
United States	73 %	73 %	76 %	78 %	85 %
Saudi Arabia	68 %	68 %	68 %	72 %	77 %
Finland	60 %	61 %	59 %	81 %	82 %
New Zealand	69 %	70 %	69 %	62 %	63 %
Australia	67 %	64 %	67 %	62 %	63 %
Iran, Islamic Rep. of	59 %	59 %	59 %	70 %	65 %
Chinese Taipei	60 %	37 %	60 %	76 %	77 %
England	64 %	64 %	63 %	56 %	63 %
Chile	63 %	63 %	N/A	74 %	74 %
Turkey	65 %	65 %	N/A	65 %	70 %
International average	47 %	46 %	49 %	57 %	58 %

Data for science and mathematics was from TIMSS 2011. Data for reading was from PIRLS 2011. Country ranking in this table was determined by an overall assessment of student sleepiness in countries who took all or most of the assessments. Other countries may report a higher percentage of student sleepiness in a single assessment. Palestinian reported the highest percentage (82 %) of student sleepiness in 8th grade mathematics among all TIMSS participants. France reported the highest percentage (80 %) in 4th grade reading among all PIRLS participants

quality and insufficient sleep in high school students increased from 31 % in 2001 to 46 % in 2011. In a study of 100 U.S. adolescents aged 12 to 18 (Calamaro et al. 2009), 79 % slept less than 8 h per night and 33 % reported falling asleep in school. In the study of Gaina et al. (2007) that surveyed 9,261 school children aged 12 to 13 in Japan, 25 % of students reported "almost always sleepy" and 48 % "often sleepy." A cross-sectional study of 20,778 children aged 5 to 12 in China found that the prevalence rate of daytime sleepiness was 64 % (Li et al. 2013).

Sleep deprivation is not only highly prevalent but also chronic among adolescents. In a two-wave cohort study of 4,175 U.S. adolescents aged 11 to 17 at baseline and 3,134 of those a year later (Roberts et al. 2009), the percentage of adolescents reporting 6 h or less of sleep on weeknights increased from 20 % in the first year to 25 % in the second year. The sleeping behaviors of about half (54 %) of the adolescents who slept 6 h or less on weeknights in the first year remained so a year later, suggesting sleep deprivation is persistent.

4 Lack of attention to sleep deprivation by educational researchers

Despite the fundamental role of adequate sleep in cognitive and social functioning of students, however, educational researchers have rarely paid attention to this important issue. For example, although students in the United States were reported to show the highest rate of sleepiness, this issue did not receive any attention in the widely cited national reports by the U.S. National Center for Education Statistics for the TIMSS and PIRLS 2011 results (Provasnik et al. 2012; Thompson et al. 2012).

The lack of attention to the sleep deprivation in students by educational researchers and policy makers is not just limited to the TIMSS and PIRLS results. We examined 12 of high-impact international journals that publish a broad range of topics related to educational research and policy such as *Educational Researcher*, six major subject-specific journals such as *Journal of Research in Science Teaching,* seven major educational technology journals such as *Computers & Education,* and five journals that focus on educational administration and school improvement, such as *School Effectiveness and School Improvement*.[1] Out of over 23,000 articles published by the 30 international journals between 2000 and 2014, only two studies focused on student sleep, both arguing for a later school start time to increase sleep hours for adolescent

[1] The 12 major educational research journals we examined include *Educational Researcher, American Educational Research Journal, Review of Educational Research, Journal of the Learning Sciences, Learning and Instruction, Instructional Science, Elementary School Journal, British Educational Research Journal, Teachers College Record, Educational Evaluation and Policy Analysis, Educational Psychologist,* and *Journal of Education Policy,* six major subject-specific journals, including *Journal of Research in Science Teaching, Science Education, International Journal of Science Education, Reading Research Quarterly, Journal of Adolescent & Adult Literacy,* and *Journal for Research in Mathematics Education,* seven major educational technology journals, including *Computers & Education, Journal of Computer Assisted Learning, British Journal of Educational Technology, Educational Technology & Society, Educational Technology Research and Development, Learning Media and Technology,* and *Interactive Learning Environments,* and five journals that focus on educational administration and school improvement, including *Education and Urban Society*, *Educational Administration Quarterly*, *Educational Management Administration & Leadership*, *School Effectiveness and School Improvement*, and *Improving Schools*.

student (Kirby et al. 2011; Mitru et al. 2002). For example, Kirby and colleagues (2011) reviewed evidence from the Minneapolis Public School District in the United States who delayed their start times, and suggested that schools should set later start times to better match the sleep-wake cycle of adolescents. Mitru et al. (2002) made a similar argument for delaying school start times to increase sleep hours for high school students. Other than the two articles, little discussion existed on student sleep in these major educational research journals.

Substantial evidence from research in sleep science, pediatrics, public health, and psychiatry suggested that sleep deprivation has serious consequences on both physical and mental health, as well as academic performance. These studies were often published by journals such as *Sleep Medicine*, *Journal of Sleep Research*, *Sleep Medicine Reviews*, and *Pediatrics*. According to citation analysis via Google Scholar and the Web of Science, these studies were rarely cited by educational researchers. Such a lack of attention to student sleep by educational researchers is surprising, as sleep is basic to human functioning, including learning. Simply put, innovative pedagogical interventions and school reform efforts are not likely to be effective if students are too sleepy to focus.

5 Consequences of sleep deprivation

In TIMSS and PIRLS 2011, students who experienced lack of sleep tended to have lower scores than their peers who had enough sleep. As shown in Table 2, the reading, mathematics, and science average scores of fourth grade students who lacked sleep were 507, 486, and 481, respectively, compared to 518, 497, and 492 of peers who did not. The mathematics and science average scores of eighth grade students who lacked sleep were 461 and 473, respectively, compared to 477 and 484 of peers who did not. As shown in Table 3, *t*-test analysis of all TIMSS and PIRLS participating countries and regions showed that the differences in science, mathematics, and reading average scores between students who lacked sleep and who did not were statistically different for fourth grade and eighth grade students. On average, not sleepy students outperformed sleepy students by at least 10 points in the average scores for all tests. Figure 1 illustrates the differences in the average scores of sleepy and non-sleepy students in TIMSS and PIRLS 2011.

Table 2 Average scores of students whose teachers reported their instruction was not limited by student sleepiness or limited to the degree of "some" or "a lot"

	N	"Not at all" Mean (Std.)	"Some" or "A Lot" Mean (Std.)
Fourth grade reading	46	518.30 (55.07)	506.89 (53.23)
Fourth grade mathematics	50	497.02 (72.33)	485.60 (72.22)
Fourth grade science	50	492.26 (75.68)	480.74 (76.48)
Eighth grade mathematics	42	476.67 (70.56)	461.26 (68.41)
Eighth grade science	42	483.76 (61.70)	472.95 (60.29)

Table 3 T-test results for the differences in average scores between not sleepy and sleepy students

	Mean	Std.	*t*	df	Sig. (2-tailed)
Fourth grade reading	11.41	9.51	8.14	45	0.0000
Fourth grade mathematics	11.42	12.17	6.63	49	0.0000
Fourth grade science	11.52	11.83	6.88	49	0.0000
Eighth grade mathematics	15.41	14.73	6.78	41	0.0000
Eighth grade science	10.81	14.65	4.78	41	0.0000

Consistent with the TIMSS and PIRLS results, prior research has reported the negative impact of inadequate sleep on school performance. As summarized in recent reviews on this topic (Beebe 2011; Dewald et al. 2010; Shochat et al. 2014; Curcio et al. 2006), research has shown an association between sleep deprivation and poor academic performance. In a five-year longitudinal cohort study that followed 612 children in China from first to fifth grade, Li et al. (2013) found that both daytime sleepiness and short sleep duration were associated with poor academic achievement. Similarly, in another study that analyzed the relationship of sleep duration with academic achievement in a sample of 2,716 adolescents in Switzerland (Perkinson-Gloor et al. 2013), students who slept less than 8 h per night had lower school grades, as compared to those who slept longer hours. A meta-analysis of 50 studies involving a total of 48,360 children and adolescents found that poor sleep quality, insufficient sleep, and daytime sleepiness were all significantly associated with poor school performance (Dewald et al. 2010).

In addition, sleep deprivation was associated with attention deficit (Lehto and Uusitalo-Malmivaara 2014), poor memory (Dworak et al. 2007), risky behaviors (Shochat et al. 2014), depression (Beebe 2011), suicidal thoughts (Do et al. 2013), child obesity (Chen et al. 2008; Shochat et al. 2014), and substance use (Pasch et al. 2012). In a review of 17 studies on sleep and child obesity, Chen et al. (2008) found that children with shorter sleep duration had a 58 % higher risk for obesity than peers with adequate sleep. Longitudinal studies found that sleep problems in childhood predicted anxiety, depressive symptoms, and substance abuse in later life, especially for children from low-income families

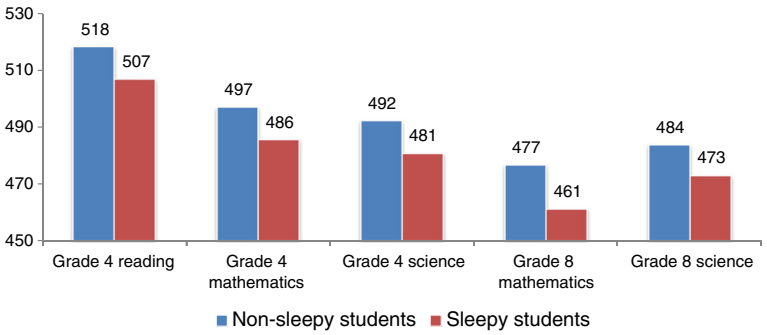

Fig. 1 The average scores of sleepy and non-sleepy students in TIMSS and PIRLS 2011

(Beebe 2011). In conclusion, chronic insufficient sleep can have costly consequences and can fundamentally alter a child's long-term development.

6 Heavy media use and sleep deprivation

Although the 2011 TIMSS and PIRLS did not specify the causes for sleep deprivation in students, prior research indicated that early school start time (Kirby et al. 2011), poor sleep environment (Moore and Meltzer 2008), intake of caffeine before bedtime (Calamaro et al. 2009), extracurricular activities and after-school jobs (Moore and Meltzer 2008), and biological changes during puberty (Owens et al. 2014) may all lead to sleep loss. In particular, heavy media use that has become increasingly prevalent among school-aged children and adolescents in the last decade may be an important contributor to the sleep deprivation in students. Heavy media use, such as televisions, smartphones, tablets, computers, Internet, and game consoles is prevalent among children, particularly in developed countries. Using the 2007 National Survey of Children's Health data in America, Wethington et al. (2013) found that 21 % of children aged 6 to 11 and 26 % of adolescents aged 12 to 17 in the United States had excessive screen time, defined as spending more than 2 h per day watching televisions and videos and playing video games. This study did not even include the time that children and adolescents spent on other types of media use, such as surfing the Internet or texting. Baer et al. (2012) reported that 11–17 year olds in Canada spent 4.5 h per day on televisions, computers, and game stations. In another study of a nationally representative sample of 2,002 U.S. youth aged 8 to 18 (Grades 3–12), Rideout et al. (2010) found that on average these children and adolescents spent about 7.5 h per day on media use including TV, music, computers, and video games. This study also found that media use varied by age (Rideout et al. 2010). Children aged 8 to 10 spent about five and half hours, early teenagers (11- to 14-year-olds) spent 8 h and 40 min, and adolescents (15- to 18-year-olds) spent 8 h on media.

Younger children also spend a considerable amount of time on media. Vandewater et al. (2007) found that media use was common among infants, toddlers, and preschoolers, leading to a digital childhood. A more recent study by Common Sense Media (2013) found that, as of June 2013, 72 % of children aged 8 and under in the United States had used a mobile device for media activities, such as playing games or using apps, almost doubled from 38 % in 2011. This study found that children aged 0 to 8 spent an average of 1 hour and 55 min per day on televisions, video games, computers, and mobile devices, compared to only 28 min on reading. Older children spent more time on screen media. Screen time ranged from an average of 58 min among children under 2, 1 hour and 58 min among children aged 2 to 4 and two hours and 21 min among 5- to 8-year-olds (Common Sense Media 2013).

It should be noted that adolescents and young children have different sleep patterns. The biological changes that occur as children grow into adolescents will lead to a physiological preference for delayed bedtime (Kirby et al. 2011). Also, adolescents may spend more hours on media use than younger children (Rideout et al. 2010). Together these factors may explain the larger percentages of 8th grade teachers who reported student sleepiness than 4th grade teachers in the TIMSS 2011 (Mullis et al. 2012a).

Despite the variances in specific hours on media use reported in different studies, there is little argument that youth in general are heavy media users. Heavy media use interferes with sleep by delaying bedtime and causing a higher level of arousal in the nervous system that makes it harder to fall asleep (Chahal et al. 2013; Wethington et al. 2013; Calamaro et al. 2009). In addition, exposure to screen lights in evenings disrupts one's circadian rhythms and reduces the release of hormone melatonin in the brain that triggers sleep (Cajochen et al. 2011). In a study by the National Sleep Foundation (2011), researchers interviewed 1,508 Americans aged 13 to 64 concerning their technology use and sleep qualities, including 171 adolescents aged 13 to 18. This study found that adolescents were the heaviest media users before bedtime among all age groups. They were much more likely to use cell phones, send texts, surf the Internet, use social networking sites, watch video, play games, listen to music, and use Skype in the hour before trying to go to sleep. For example, 72 % of adolescents used cell phones in the hour before bedtime, as compared to 39 % of the entire sample. Consequently, almost half of the adolescents (46 %) reported that they rarely or never slept well on weeknights and felt tired when they woke up in the morning. Similar findings were reported for adolescents in the United Kingdom. Arora et al. (2013) examined the relationship of four types of technology use (computers, mobile telephones, televisions, and video games) with sleep duration on weekdays. This study found that technology use at bedtime was highly prevalent among UK adolescents, as 85 % reported using at least one type. Each type of technology use was significantly associated with reduced sleep duration on weekdays (Arora et al. 2013).

Two comprehensive reviews on media use and sleep among school-aged children and adolescents provided compelling evidence for the negative impact of media use on sleep duration and quality (Cain and Gradisar 2010; Hale and Guan 2015). Cain and Gradisar (2010) reviewed 36 studies that examined the impact of media use on the sleep of children and adolescents aged 5 to 17. This review found that media use was consistently associated with later bedtime and shorter total sleep duration. In the latest review on media use and sleep among school-aged children and adolescents, Hale and Guan (2015) examined 67 studies published between 1999 and early 2014, including 31 new studies not included in the review by Cain and Gradisar (2010). Out of the 67 studies, 26 involved children younger than 10 years old (e.g., Foley et al. 2013; Magee et al. 2014). Hale and Guan found that screen time was associated with later bedtime and shorter sleep duration in 90 % of the studies they reviewed. The authors suggested that "Youth should be advised to limit or reduce screen time exposure, especially before or during bedtime hours to minimize any harmful effects of screen time on sleep and well-being" (Hale and Guan 2015, p. 50).

Parallel to what has been found about sleep deprivation, excessive media use was linked to poor academic performance (Weis and Cerankosky 2010; Stavropoulos et al. 2013), attention deficit (Weinstein and Weizman 2012), impaired memory (Higuchi et al. 2005), depression (Romer et al. 2013), suicidal thoughts (Messias et al. 2011), and child obesity (Wethington et al. 2013; Chahal et al. 2013). This similarity can be explained by the high concurrence of excessive media use and sleep problems. A study found that 52 % of Chinese adolescents in Hong Kong who were identified as Internet addicts also experienced insomnia (Cheung and Wong 2011). Based on a sample of 2,336 high school students in South Korea, Choi et al. (2009) found that the prevalent rate of excessive daytime sleepiness among all participants was 11 %, as compared to

38 % in students considered Internet addicts. Clearly, excessive media use is one important contributor to sleep problem and other dysfunctions.

Compared to other types of media use, playing online and mobile games is particularly popular among children and adolescents (Blades et al. 2013). Children and adolescents are avid digital game players (Hofferth 2010; Jackson et al. 2005; Kerawalla and Crook 2002; Casey et al. 2012). A study of 8,568 nine-year-old children in Ireland found that 87 % of the children played computer games at home (Casey et al. 2012). Kerawalla and Crook (2002) found that children in Britain mainly used their computers to play games, rather than the educational software programs that their parents purchased for them to use. A study by the Pew Research Center found that 97 % of adolescents aged 12 to 17 in the United States played games on computers or consoles, and half reported playing games the day prior to the survey (Lenhart et al. 2008).

In addition, data from web analytics on game websites and mobile analytics on game apps sheds light on the number of players and the amount of time on games. Web analytics provides insights into website traffic and user behaviors for a specific website, including number of visits, time on website per visit, and number of pages viewed. Mobile analytics provides similar data for apps, software applications designed for smartphones and tablets, such as number of downloads, and time on apps. These independent data sources provide additional evidence for the prevalence of electronic game play as found in the research literature discussed earlier.

7 Use of online games

Traffic data for 10 popular game websites appealing to children and adolescents during the period from January 2013 to December 2013 was retrieved from Compete (www.compete.com), a widely used third-party web analytics service. Compete reports web traffic estimates based on a sample of 2 million U.S. Internet users, who willingly provided anonymous Internet usage information to the company for marketing research. The sample is about 1 % of total Internet users in the United States.

Table 4 shows the average number of unique visitors and visits per month to these game sites from January to December 2013, the average time on website per visit, and the total time on website per month. All visits were made by Internet users in the United States. Although it is unclear how many of the users were children and adolescents, prior research has shown that children and adolescents are avid online game players (Lenhart et al. 2008; Kuss and Griffiths 2012). According to a study by Entertainment Software Association (2014) that surveyed over 2,200 nationally representative households in the United States, overall 29 % of computer and video gamers were under 18 years old. The content of most of the websites in Table 4 is geared towards youth. For example, CartoonNetwork.com is a popular entertaining website that offers cartoon animations primarily for children and adolescents (Kalagian 2007). Therefore, it seems reasonable to assume that a substantial amount of users of these websites are youth.

To understand the magnitude of the hours spent on the games, it is useful to compare with the instructional time that students receive. Mathematics is a major subject in elementary schools. Recent research showed that elementary students in the United States receive about 140 h of instruction on mathematics per year (Phelps et al. 2012).

Table 4 Site traffic statistics for 10 popular children-oriented game websites from January to December 2013

Game sites	Average monthly unique visitors	Average monthly visits	Average time on site per visit (in minute)	Average time on site per month (in hour)
Pogo.com	24,697,731	146,918,600	17.7	42,574,233
Roblox.com	7,108,544	61,307,133	18.5	18,834,064
Cartoonnetwork.com	5,898,774	17,072,122	18.2	5,257,363
Pbskids.org	5,468,968	18,236,963	23.9	7,286,449
Nickjr.com	5,333,517	16,559,149	23.6	6,561,788
Bigfishgames.com	5,317,028	22,971,581	7.0	2,688,513
Girlsgogames.com	4,488,006	11,606,829	17.9	3,470,925
Poptropica.com	4,426,433	14,656,578	12.9	3,080,552
Y8.com	4,293,946	14,685,806	14.1	3,513,345
Miniclip.com	4,064,011	14,169,032	10.4	2,439,964
Total				95,707,196

There are about 22 million K-5 students in the United States (Keaton 2012). Therefore, the total instructional time for mathematics for all U.S. elementary students is 3,080 million hours per year, and 257 million hours per month.

As shown in Table 4, each month millions of U.S. users made millions of visits to these game websites. The total time that U.S. users spent on the 10 game websites in the last year was equivalent to 37 % of instructional time that all U.S. elementary students received for mathematics. It should be noted that there are many other game websites with similar or slightly less popularity. For example, PopCap is one of the major game publishers, who produced popular games such as *Plants vs. Zombies*. According to its statistics,[2] gamers spend 3 billion hours playing PopCap games across all platforms each year. In other words, time spent on PopCap games is equivalent to the instructional time for mathematics for all U.S. elementary students.

8 Use of mobile games

In recent years, mobile devices such as smartphones and tablets have quickly gained popularity among youth. For example, almost half (47 %) of U.S. adolescents aged 12 to 17 owned smartphones (Madden et al. 2013). Also, 50 % of American adults with children at home owned tablets (Zickuhr 2013). Parents reported that the most common use of tablets by their children was to play downloaded games, which was much more frequent than educational use of the devices (Nielsen 2012). The number of applications designed for mobile devices has experienced exponential growth over the last

[2] Data was retrieved from http://popcap.mediaroom.com/index.php?s=30842 on September 20, 2014.
[0] Data was retrieved from http://www.appannie.com/search/?vertical=apps&market=ios and http://www.appannie.com/search/?vertical=apps&market=google-play on January 16, 2015.
[0] Data was retrieved from http://www.pocketgamer.biz/metrics/app-store/ on January 20, 2015.
[0] Data was retrieved from http://www.appbrain.com/stats/android-market-app-categories on January 20, 2015.

several years. As of January 2015, according to App Annie, a leading mobile analytics company, there were over 1.4 million apps for iOS devices in the App Store and 1.7 million apps for Android devices in Google Play.[3]

The largest category of apps is games in both the iOS App Store and Google Play. The latest statistics showed that there are over 310,000 game apps in the iOS App Store [4] and over 260,000 game apps in the Google Play store.[5] Each day 185 new game apps are submitted to the App Store.[4] Games constitute over 40 % of the downloads and over 75 % of the revenues of the App Store and Google Play (App Annie, and IDC 2013). In 2012, over 20 billion games had been downloaded by smartphone and tablet users. Consumer spending on games in the App Store had exceeded that of dedicated handheld game players, such as Nintendo and Sony PlayStation (App Annie, and IDC 2013).

A study by the NPD Group (2013) that involved 3,842 children in the United States found that youth aged 12 to 17 spent 5 h per week playing mobile games in 2011 and 7 h in 2013, a 40 % increase in hours from 2011. Also, children who played mobile games were younger in 2013 than in 2011, and the authors believed that such trends would continue as the gaming industry further adopts mobile technology (NPD Group 2013). Similarly, according to Flurry, a mobile Analytics company, users spent an average of 2 h and 38 min on their mobile devices every day, among which about one third (51 min) was spent on games (Khalaf 2013). Based on data from 44,295 iOS devices that Flurry tracked, in May 2013, peak usage of iPhones and iPads occurred at around 8–10 pm, right before typical bedtime for children (Gordon 2013). In particular, there was a considerable amount of active usage from midnight through 8 am. Although it is unclear how many of those non-sleeping users were children and adolescents, it is an alarming trend to watch.

Popular children games often appear among the top apps with the largest number of downloads in the app stores. For example, in July 2013, the top 10 revenue generating apps in the iOS App Store were all games.[6] To illustrate the amount of time spent on the game apps, three games appealing to children are analyzed as examples.

Plants vs. Zombies 2 was released on August 15, 2013. In 2 weeks, this game had been downloaded 25 million times globally, and players had spent over 81 million hours in the game (EA Staff 2013). Another popular children's game, *Despicable Me: Minion Rush*, based on the animated movie, *Despicable Me 2*, was released in June 2013. In 3 months, this game had been downloaded over 100 million times, and players had spent 266 million hours in the game (Ankur 2013). Another example is *Angry Birds*. Since released in 2009, it had passed one billion global downloads, and had consumed 200,000 years of human time. Players spent 5 million hours in this game per day (9to5mac 2012). Together players spent roughly 399 million hours per month on the three games alone, which is about 155 % of instructional time for mathematics received by all U.S. element students.

[3] Data was retrieved from http://www.appannie.com/search/?vertical=apps&market=ios and http://www.appannie.com/search/?vertical=apps&market=google-play on January 16, 2015.
[4] Data was retrieved from http://www.pocketgamer.biz/metrics/app-store/ on January 20, 2015.
[5] Data was retrieved from http://www.appbrain.com/stats/android-market-app-categories on January 20, 2015.
[6] Data was retrieved from http://www.distimo.com/blog/2013_08_top-global-apps-july-2013/ on September 20, 2014. Distimo is a mobile Analytics company.

9 Conclusion

Improving student sleep requires collective efforts from schools, parents, and students themselves. First, parents should pay more attention to their children's sleep. A study by the National Sleep Foundation (2006) found that although 51 % of adolescents reported lack of sleep, only 9 % of parents were aware of their children's sleep problem. Also, computer and Internet use at home tends to be spontaneous and unstructured, and lack adult supervision (Jewitt and Parashar 2011). Parents should be better aware of their children's technology use and sleep issues, and develop routines to increase both sleep duration and quality in children and adolescents. Jones et al. (2013) found that providing a brief informational brochure to parents significantly increased their knowledge regarding children's healthy sleep and their intention to make positive changes to their child's sleep routine. Such educational interventions should be available to parents.

Prior research suggested that to improve sleep duration and quality, electronic entertainment devices, including televisions, computers, game consoles, music players, and mobile phones should be kept out of bedrooms (Cain and Gradisar 2010). Another simple strategy that parents can adopt is to set bedtimes for their children. Short et al. (2011) found that parents-set bedtimes were associated with earlier bedtimes, longer sleep duration, and less daytime fatigue and sleepiness. Yet, this study also found that only 18 % of adolescents reported that their parents set bedtimes for them on school nights.

In addition, school-based sleep education programs can help to increase students' sleep knowledge and promote healthy sleep habits (Kira et al. 2014). To be successful, such programs should not only focus on imparting knowledge about sleep, but also help students to develop motivation and skills in effecting long-term behavioral changes in sleep (Cain et al. 2011). To date, sleep education is still in its infancy and few schools are offering sleep education programs to students due to low awareness of sleep problems in students in the education community (Blunden et al. 2012).

Mobile devices are becoming common household commodities, which makes it even more convenient for children and adolescents to play games and use other media. As found in the study by the NPD Group (2013), there was a 40 % increase in hours that youth spent on mobile games from 2011 to 2013. Future research should closely monitor the trend of heavy media use and understand its impact on student sleep. More importantly, future research should develop innovative sleep education programs offered to students, parents, and teachers, and evaluate the effectiveness of these programs.

How students perform in school during daytime has much to do with what they do at home in evenings. Educational research tends to adopt a piecemeal approach to student learning that fails to view students as whole persons whose physical, cognitive, behavioral, and emotional functioning is intertwined. Adequate sleep is essential for healthy development of children and adolescents. Poor sleep leads to daytime fatigue, sleepiness, energy loss, and emotional disturbance (Beebe 2011), which all affect one's ability to learn. In summary, parents, educational researchers, and policy makers should be better aware of the prevalence of sleep deprivation in students and develop programs and intentions to address the negative impact of heavy media use on student sleep.

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