**The effects of video-games on students’ motivation to math: A meta-analysis in K-12**

To contrast the decline of enrolments in STEM field (science, technology, engineering and mathematics) in many country (OECD, 2013) and promote students’ interest and achievement in science and mathematics one approach that receive much attention in both elementary and secondary schools is the use of educational technology.

Evidence-based research suggested that incorporate technology in the mathematical classroom generally produce a positive effect in comparison to traditional methods, and that the impact is variable by educational technology type (Cheung & Slavin, 2013).

Recently, an increasing number of studies investigated the educational benefits of digital games in encouraging mathematical learning and attitudes (e.g. Erhel & Jamet, 2013; Kebritchi, Hirumi, Bai, 2010).

Video-games…

**Motivation to math**

To understand the reasons that lead a student to do a determined task, such as a math homework, that influence its performance and persistence in the face of difficulties it is necessary to explore motivation-related constructs (Wigfield & Cambria, 2010).

For example, concerning performance in different domains such as math, expectancies for success and related construct as self-efficacy or confidence, that have a central role in many motivational theories (Bandura, 1997; Atkinson, 1957, Eccles et al., 1983), are considered the strongest psychological predictors of achievement ( e.g., Eccles & Wigfield, 2002). Career aspiration and current activity choice, including taking math classes are instead mainly influenced by the subjective value placed on the task (e.g., Wigfield & Eccles, 2000). Values primarily studied from the perspective of expectancy-value theory (Eccles, et al., 1983) are a broad construct that include needs, goals, and motivational orientations and they reflect the different importance, interest or utility assigned by various individuals to the same activity.

Recent Meta-Analyses…

**Objectives**

Aim of the present meta-analysis is to answer the following research questions:

1. How does the usage of video-games influence students’ motivation to math?

2. The length of the intervention exerts a substantial influence on this effect?

3. The type of technological support (personal computer, console, app) influence the success of the intervention?

4. There are substantial differences depending on level of education (primary vs. secondary)?

**Methods**

The protocol for this meta-analysis was developed according to the Preferred Reporting Items for Systematic review and Meta-Analysis Protocols (PRISMA-P; Moher, Liberati, Tetzlaff, & Altman, 2009).

**Eligibility criteria**

For examining the effect of video-games on students motivation to math (In order to answer the research questions), the following criteria were established.

1. Study characteristics: studies could have taken place in any country, but the report of the study had to be available in English; studies had to have been carried out after 2000; peer-reviewed journal, conference papers and unpublished dissertations were included.

2. Types of participants: studies had to be conducted on K-12 students (between 1st to 12th grade); studies conducted exclusively among students with disabilities were not considered because are beyond the scope of this meta-analysis.

3. Types of interventions: studies had to use experimental methods with random assignment to treatment and control conditions, or quasi-experimental methods in which treatment assignments were specified in advance. Studies that matched a control group to the treatment group after posttest outcomes (post-hoc quasi-experiments or ex post facto designs) were not included; studies had to compare experimental groups using video-games to control groups using an alternative program already in place, or “business-as-usual”; studies had to provide pretest data.

4. Types of outcome: studies had to report at least one measure of motivation to math; the quality of the instrument had to be validated in a previous publication, or reliability statistics had to be reported in the publication.

5. Types of data: studies had to report: sample sizes, arithmetic means and standard deviation of both the experimental and the control groups to calculate effect size.

**Information sources**

A systematic search for studies on motivation to math through June 2019 was conducted of the following electronic databases: ERIC, OVID: Psycinfo; SCOPUS, EBSCO: Education Source, Proquest. Topic journals archive and reference lists of quantitative studies, literature review, and meta-analyses were also handchecked for additional articles.

**Literature Search**

Terms related to video-games (video game\* or computer game\* or serious game\* or educational game\* or digital game\* or game-based learning) had to be present in the abstract.

Terms related to learning domain (mathematics or math or algebra or arithmetics or geometry or numeracy), grade (K-12 or school or primary education or secondary education), outcome (motivation or engagement), study design (RCT or experiment or quasi experiment or control group or matched groups or effect size) were searched on the full-text. Limits on the search were studies from 2000 to current and English language.

**Study selection and data collection process**

Eligible publications were screened at the abstract and full-text levels by three independent reviewers. In all the steps, the team regularly met up to discuss the doubtful cases in order to ensure the quality of the selection process.

**Summary measures**

Sample sizes, arithmetic means and standard deviation were extracted from the primary studies to calculate a univocal indicator of effect size. Moreover, data concerning: grade level, type of video-game device and length of the intervention were coded from each study and examined as potential effect size moderators.

**Synthesis of results**

*Calculation of Effect Size:* To estimate the effect size from the initial mean differences, we used the Morris (2008) procedure implemented in the Metafor package for R which allows to compute a standardized effect size measure for pretest posttest control group designs. Indeed, the effect size (dppc2) take into account changes in both the treatment and control group and provides an unbiased estimate of the population effect size.

Since the data available from previously published papers in this area were insufficient, the relationship between pretest and post-test scores was set at r = 0.6. We also conducted a sensitivity analysis to ensure that the conclusions from the meta-analysis are unchanged when those correlations are varied.

*Effect Size Aggregation:* To address dependency among effect sizes (e.g., multiple-treatment and multiple-endpoint studies), we used the Gleser and Olkin’ (1994) procedure implemented in the MAd package (Del Re & Hoyt, 2014) for R statistics program. A within-study correlation of r = 0.5 was assumed (Wampold et al., 1997).

**Results**

**Study selection**

As shown in Figure 1 (Moher, Liberati, Tetzlaff, Altman, & the PRISMA Group, 2009), eligible publications (n = 1921) were first screened at the abstract level by three independent reviewers; second at the full-text level (n = 165), in which all studies previously identified as potentially eligible at the abstract level were screened for final eligibility.

Several studies (n = 128) were excluded because not focused in math domains or in motivation to math, did not include pre-test, control group or also the control group use video-games. Of the remaining eligible studies (n = 37), some studies (n = 18) were excluded because presented overlapping data (n = 6) or not all relevant data (sample sizes, arithmetic means and standard deviation) required to calculate the effect size were reported (n = 12).

Authors of these primary studies were contacted to ask for required data, but they did not answer. In all the steps, the team regularly met up to discuss the doubtful cases in order to ensure the quality of the selection process. Finally, 19 studies were identified as adequate for the purpose of this meta-analysis.

**Multiple Effect Size**

In the included publications we found different sources of effect size dependence (Gleser & Olkin, 2009).

*Multiple-treatment study*: Ke (2008) compared multiple experimental conditions (cooperative, competitive and individualistic) with a common control.

*Multiple-endpoint studies:* Pareto et al. (2011), Riconscente (2013) and Starkey (2013), investigated two different motivational constructs in common subjects, therefore, the effects for these measures were correlated. Four studies (Mavridis, Katmada, & Tsiatsos, 2017; McCue, 2011; Rodríguez-Aflecht et al., 2015; Starkey, 2013) used multidimensional instruments that reflect different aspects of motivational construct. We considered all the dimensions effect sizes, but we account for dependence among them.

Concerning other publications, in a study (Ke, 2006) three different treatment conditions were compared with three different comparable control groups; therefore, we analyzed them separately, as independent effect sizes. One study (Chang et al., 2016) reported data from girls and boys separately, but in the analysis we included the combined results; moreover, the authors examined three different sub-domains of engagement (behavioral, emotional, cognitive), but we considered only the cognitive engagement essentially defined in the study as motivation (Fredricks et al. 2004).

**Study characteristics**

Our research included 19 studies reporting a total of k = 42 effects size. Despite we collected the studies published since 2000 it was found that no studies satisfying the criteria were published before 2006. Most of the study were published in peer-review journal and …

(see Table…)

**Figure 1.** Flow diagram detailing the article screening, selection, and eligibility process

## Identification

Records identified through database searching  
Educational Source (n = 420)

ERIC (n = 158)

Psychinfo (n = 102)

Proquest (n = 937)

SCOPUS (n = 417)

## Included

## Eligibility

## Screening

Studies included in quantitative synthesis (meta-analysis)  
(n = 19)

Eligible articles excluded for data issues  
(n = 18)

Preliminary eligible studies   
(n = 37)

Full-text articles assessed for eligibility  
(n = 165)

Records screened  
(n = 1921)

Full-text articles excluded because not fulfill the inclusion criteria  
(n = 128)

Records excluded  
(n = 1756)

Additional records identified through other sources  
(n = 61)

Records after duplicates removed  
(n = 1921)

Table 1:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *cod* | *Authors* | *Publication Sources* | *Math domain* | *Grade* | *Sample size* | *Number of effect size estimated* |
| 54 | Bai, Pan, Hirumi, & Kebritchi (2012) | Journal | algebra | 8 | 437 | 1 |
| 961 | Ke (2006) | Dissertation | math | 5 | 358 | 3 |
| 432 | Ke (2008) | Journal | math | 5 | 160 | 3 |
| 436 | Kebritchi, Hirumi, & Bai (2010) | Journal | algebra | 9-10 | 193 | 1 |
| 982 | LaDonna, (2018) | Dissertation | math | 4 | 80 | 1 |
| 983 | Rodríguez-Aflecht, et al. (2015) | Journal | arithmetic | 4-6 | 1168 | 4 |
| 964 | Starkey (2013) | Dissertation | proportions, ratios, fractions | 6-8 | 168 | 9 |
| 584 | Mavridis, Katmada, & Tsiatsos (2017) | Journal | arithmetic, algebra,  geometry | 7-8 | 79 | 4 |
| 610 | Miller, & Robertson (2011) | Journal | calcolous | 6 | 633 | 1 |
| 452 | Kim, Ke, & Paek, (2017) | Journal | fractions | 4 | 132 | 1 |
| 669 | Pareto, Arvemo, Dahl, Haake, & Gulz, (2011) | Conference Paper | arithmetic | 3 and 5 | 143 | 2 |
| 971 | Chang et al. (2016) | Journal | fractions | 5 | 90 | 1 |
| 959 | Hung, Huang, & Hwang (2014) | Journal | geometry | 5 | 46 | 1 |
| 476 | Ku, Wu, Lao, Wang, & Chan (2014) | Conference Paper | mental  calculation | 4 | 59 | 1 |
| 988 | Main & O’Rourke (2011) | Journal | maths functions | 4-5 | 56 | 1 |
| 985 | Abdelhafez (2016) | Dissertation | algebra | 10-11 | 40 | 1 |
| 611 | Miller & Robertson (2010) | Journal | mental computation | 6 | 40 | 1 |
| 935 | Riconscente (2013) | Journal | fractions | 5 | 94 | 2 |
| 990 | McCue (2011) | Dissertation | math | 6-7 | 43 | 4 |

Table 2:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *cod* | *Authors* | *Device* | *Game* | *Intervention weeks*  *(sessions)* | *Intervention: minutes for sessions* |
| 54 | Bai, Pan, Hirumi, & Kebritchi (2012) | pc | *DimensionM*, 3-D mathematics instructional games | 18 | N/A |
| 961 | Ke (2006) | pc | *Astra Eagle*, web-based drill-and-practice programs | 4 (8) | 45 |
| 432 | Ke (2008) | pc | *Astra Eagle*, web-based drill-and-practice programs | 4 (8) | 40 |
| 436 | Kebritchi, Hirumi, & Bai (2010) | pc | *DimensionM*, 3-D mathematics instructional games | 18 (18) | 30 |
| 982 | LaDonna, (2018) | pc | *DreamBox* Learning system | 7 (7) | 45 |
| 983 | Rodríguez-Aflecht, et al. (2015) | pc | *Number Navigation,* game-based learning environment | 10 | at least 30 |
| 964 | Starkey (2013) | pc | *Lure of the Labyrinth,* serious digital game | 9 (9) | 30 |
| 584 | Mavridis, Katmada, & Tsiatsos (2017) | pc | educational game | 14 | N/A |
| 610 | Miller, & Robertson (2011) | console | *Nintendo DS Lite,* *Dr. Kawashima’s Brain Training* | 9 (45) | 20 |
| 452 | Kim, Ke, & Paek, (2017) | pc | Game-based  learning in a open simulator | 1 | 30-40 |
| 669 | Pareto, Arvemo, Dahl, Haake, & Gulz, (2011) | pc | *Teachable Agent Arithmetic Game,* educational game | 9 (9) | 40 |
| 971 | Chang et al. (2016) | app | Educational game software application, *iOS* mobile devices | 2 (8) | 20 |
| 959 | Hung, Huang, & Hwang (2014) | app | Educational games, *Android* operation system | 1 (1) | 240 |
| 476 | Ku, Wu, Lao, Wang, & Chan (2014) | pc | Mini games | 5 (10) | 20 |
| 988 | Main & O’Rourke (2011) | console | *Nintendo DS Lite,* *Dr. Kawashima’s Brain Training* | 10 | 20 |
| 985 | Abdelhafez (2016) | pc | Math games software | 6 (12) | 41 |
| 611 | Miller & Robertson (2010) | console | *Nintendo DS Lite,* *Dr. Kawashima’s Brain Training* | 10 (40) | 20 |
| 935 | Riconscente (2013) | app | *Motion Math, iOS* mobile devices | 1 (5) | 20 |
| 990 | McCue (2011) | pc | Game programming in MicroWorlds EX | 28 | 45 |

Table 3: Motivational Outcomes

|  |  |  |  |
| --- | --- | --- | --- |
|  | *Authors* | *Construct* | *Instrument* |
| 54 | Bai, Pan, Hirumi, & Kebritchi (2012) | Expectancy – Values | Attention, Relevance, Confidence and Satisfaction (ARCS, Keller,  1987) |
| 961 | Ke (2006) | Self-confidence, value, enjoyment, motivation | Attitudes Toward Mathematics Inventory (ATMI, Tapia & Marsh 2004) |
| 432 | Ke (2008) | Self-confidence, value, enjoyment, motivation | Attitudes Toward Mathematics Inventory (ATMI, Tapia & Marsh 2004) |
| 436 | Kebritchi, Hirumi, & Bai (2010) | Expectancy – Values | Attention, Relevance, Confidence and Satisfaction (ARCS, Keller,  1987) |
| 982 | LaDonna, (2018) | Attitude | Attitude toward mathematics dimensions of the Test of Mathematical Ability (TOMA-3, Brown, Cronin, & Bryant, 2012) |
| 983 | Rodríguez-Aflecht, et al. (2015) | Expectancy – Values | Math Motivation Expectancy - Values (Berger and Karabenick, 2011) |
| 964 | Starkey (2013) | Expectancy – Values; Attitude | Attention, Relevance, Confidence and Satisfaction (ARCS, Keller,  1987); Mathematics Attitudes Scales (Fennema-Sherman, 1976) |
| 584 | Mavridis, Katmada, & Tsiatsos (2017) | Self-confidence, value, enjoyment, motivation | Attitudes Toward Mathematics Inventory (ATMI, Tapia & Marsh 2004) |
| 610 | Miller, & Robertson (2011) | Expectancy  Self-concept | Self Description Questionnaire (Marsh, 1992) |
| 452 | Kim, Ke, & Paek, (2017) | Expectancy – Values | Attention, Relevance, Confidence and Satisfaction (ARCS, Keller,  1987) |
| 669 | Pareto, Arvemo, Dahl, Haake, & Gulz, (2011) | Expectancy  Self-efficacy | Self-efficacy scale (Pareto et al., 2011) |
| 971 | Chang et al. (2016) | Engagement | Cognitive engagement (Chang et al., 2015) |
| 959 | Hung, Huang, & Hwang (2014) | Self-efficacy | Mathematics Attitudes Scales (Fennema-Sherman, 1976) |
| 476 | Ku, Wu, Lao, Wang, & Chan (2014) | Confidence | Mathematics Attitudes Scales (Fennema-Sherman, 1976) |
| 988 | Main & O’Rourke (2011) | Expectancy  Self-concept | Mathematical Self-Concept (Gourgey, 1982) |
| 985 | Abdelhafez (2016) | Expectancy – Values | Student Motivation Survey (SMS, Abdelhafez,2016) |
| 611 | Miller & Robertson (2010) | Expectancy  Self-concept | Burnett Self Scale (BSS, Burden & Burnett, 1999) |
| 935 | Riconscente (2013) | Self-efficacy, Liking | Fractions Self-efficacy and liking (Riconscente, 2013) |
| 990 | McCue (2011) | Self-confidence, value, enjoyment, motivation | Attitudes Toward Mathematics Inventory (ATMI, Tapia & Marsh 2004) |

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