Clearing House
Unterricht

Short Review

# Digital tools in the classroom: What types of tools are out there and how can they be used effectively?

**The development of digital tools to support learning is advancing rapidly. Consequently, educators need orientation to sort through the confusion. Which of the currently available digital tools have the potential to effectively support learning in schools, from a scientific point of view? Under which conditions can their potential be leveraged? These questions are addressed in the meta-analysis by Hillmayr, Ziernwald, Reinhold, Hofer, and Reiss (2020), »The potential of digital tools to enhance mathematics and science learning in secondary schools: A context-specific meta-analysis«. It examines six different types of digital tools for their effectiveness, specifically in secondary mathematics and science education.**

**INTRODUCTION.** The buzzword »digitalization« in schools and in teaching evokes a wide variety of associations and reactions. In their meta-analysis, Hillmayr and colleagues use empirical findings to investigate how the use of digital tools in the classroom affects learning success on the one hand, and students' attitudes toward the subject in question on the other hand. In this meta-analysis, the digital tools of focus are various computer-based programs and applications designed to support the learning process at school. The type of hardware - smartphone, computer, or tablet - is not the primary consideration. The tools studied represent a spectrum of digital applications. The six types studied are briefly described below, following Hillmayr and colleagues (2017) and Nattland & Kerres (2009):

## META-ANALYSIS AT A GLANCE

| | |
|---|---|
| **Focus of the study** | Effectiveness of digital tools on learning success and attitudes towards the subject (mathematics & science) |
| **Target group** | Secondary school students |
| **Average effect size** | Medium significant effect ($g$ = 0.65) on achievement; small significant effect on attitude ($g$ = 0.45) |
| **Further findings** | Large effects on tool efficacy with teacher training |

- **Drill-and-practice programs.** This refers to classical exercise programs for repetition and practice of knowledge. Students receive feedback on their solution after each exercise. However, the students do not learn new knowledge with these programs.
- **Digital tutor systems.** Digital tutors are programs that can, in principle, take over the function of a teacher. Knowledge is mostly imparted in small learning units. In addition, the programs often offer the opportunity to practice and deepen knowledge.

- **Intelligent tutoring systems.** Intelligent tutoring systems also serve to impart knowledge and provide opportunities for practice. However, they have an additional adaptive function. Namely, content is adapted depending on the knowledge level of the students. This is done, for example, based on the difficulty of the tasks or by providing additional support.
- **Hypermedia systems.** In contrast to tutors, students here do not complete tasks along a predefined sequence, but can explore freely. Through cross-references and links, students can access various audio, visual, or video documents, thus filling individual knowledge gaps and navigating freely through the material in a self-regulated way to work through the content, for example, with an online encyclopedia.
- **Simulations: Dynamic mathematical visualization tools.** These simulations allow students to explore mathematical relationships. The main feature is the visual representation of complex mathematical relationships, such as in the GeoGebra software for the sine function.
- **Simulations: Virtual Reality.** This type of application describes learning environments in which a real situation is simulated. Here, students can grasp and comprehend complex issues - such as elaborate scientific experiments. Virtual reality applications enable experimentation without the limitations of safety issues that would be expected in a lab.

The diversity of the tools studied, on the one hand, and the focus on secondary mathematics and science, on the other, distinguish the present meta-analysis from previous work. The meta-analysis on »adaptive educational software« by Gerard and colleagues (2015; Short Review 21) is limited to more specific tools; the meta-analysis on »digital applications in mathematics« by Cheung and Slavin (2013; Short Review 7) focuses only on applications in one subject.

**WHAT IS THIS STUDY ABOUT?** First, Hillmayr and colleagues want to find out how the use of digital tools affects performance and attitudes toward the subject in question compared to lessons without them. To do so, they summarize 92 primary studies with 92 effect sizes on achievement and 16 effect sizes on attitudes. The studies were published in peer-reviewed international journals between 2000 and 2018 and include data from nearly 15,000 students. All studies are based on a (quasi-)experimental research design with a control group and were conducted in secondary science and mathematics subjects - with secondary school students, not focused on special needs. The focus of the study is clearly on tools developed for classroom use. Accordingly, computer games that function independently of instruction, for example, are excluded from the study. They also examine numerous influential and contextual factors. This could provide concrete indications for the conditions under which the applications of these tools are particularly effective. For example, they record how many students work with the same digital tool at the same time, whether they receive additional support from the teacher or classmates in doing so, whether the tool was used as a supplement to other methods in the classroom or as a substitute for certain elements of the lesson, and whether teachers were specifically trained to use these tools. In moderator analyses, they examine the influence of these factors on student achievement.

*Table 1: Overview of Moderators and Moderator Levels.*

| MODERATOR | LEVEL | EFFECT SIZE (*g*)[1] | NUMBER OF EFFECTS |
|---|---|---|---|
| **Subject-Matter** | Mathematics | 0.55* | 33 |
| | Biology | 0.59* | 22 |
| | Chemistry | 0.69* | 16 |
| | Physics | 0.80* | 19 |
| **Age Group** | Grades 5-7 | 0.62* | 18 |
| | Grades 8-10 | 0.61* | 35 |
| | Grades 11-13 | 0.71* | 27 |
| **Students per Tool** | One student | 0.46* | 29 |
| | Two students | 0.72* | 14 |
| | Three students or more | 0.46* | 11 |
| **Type of Digital Tool** | Drill- & Practice-Program | 0.58* | 4 |
| | Digital Tutor System | 0.55* | 22 |
| | Intelligent Tutoring System | 0.89* | 7 |
| | Hypermedia System | 0.40* | 10 |
| | Dynamic Mathematical Visualization Tool | 1.02* | 6 |
| | Virtual Reality | 0.63* | 36 |
| **Type of Use** | Complementary to other methods | 0.64* | 53 |
| | As a substitute for other methods | 0.51* | 29 |
| **Teacher Training*** | Yes | 0.84* | 27 |
| | No | 0.56* | 65 |
| **Student Support by** | Teacher | 0.61* | 28 |
| | Peers | 0.63* | 11 |
| | Teacher and peers | 0.54* | 22 |
| | No support | 0.37 | 5 |

**WHAT DID THIS STUDY FIND?** The results of the meta-analysis showed that overall, secondary students in science and mathematics benefit from the use of digital tools. The significant overall effect for student achievement with instruction using digital tools compared to instruction without digital tools was $g = 0.65$. The overall effect for attitudes toward the subject was also positive and significant: $g = 0.45$. The moderator analyses showed that targeted teacher training significantly improves the effectiveness of digital tool use (see Table 1). Further analyses revealed no statistically robust differences between the different moderators. Although the type of tool is not a significant moderator, descriptive evidence showed that dynamic mathematical visualization tools and (intelligent) tutoring systems had particularly positive effects on achievement. Further details and individual findings can be found in Table 1.

[1] * marks a significant effect or difference.

**HOW DOES THE CLEARING HOUSE UNTERRICHT EVALUATE THIS STUDY?** The *Clearing House Unterricht Research Group* evaluates the meta-analysis using the following five questions, guided by the Abelson criteria (1995):

**How substantial are the effects?** According to the common classification by Cohen (1988), there was a medium significant positive effect on performance and a small significant positive effect on attitude towards the respective subject. Large effects can be achieved through teacher training ($g$ = 0.84) or specialized tools, for example, with the use of dynamic mathematical visualizations ($g$ = 1.02). Such an effect means that on average, at least one out of three randomly selected students benefits from the use of the tool. These effects are notable considering that in the control conditions, the same content was learned or taught, merely without the use of the digital tools. The effects in this meta-analysis are significantly higher than in the previous studies (Cheung & Slavin, 2013: $d$ = 0.16; and Gerard et al., 2015: $g$ = 0.34). This may be due to the different selection criteria for the primary studies considered, tailored to the respective research question. Alternatively, this may be explained by the significant evolution of digital tools in recent years.

**How differentiated are the results?** The effect sizes are presented separately for the subjects of mathematics, biology, chemistry, and physics. However, there was no significant difference between the subjects with regard to the effectiveness of the digital tools. Within the secondary level, the authors distinguish between grades five to seven, eight to ten, and eleven to thirteen, and report the results broken down accordingly. Here, the analyses revealed that the effects become descriptively larger in the final years of schooling, but without significant differences. Moreover, the authors report the results for achievement and attitude toward the subject in two separate analyses. No further differentiation of the performance component (e.g., knowledge and skills) is made.

**How generalizable are the findings?** The positive effects of the digital tools prove to be very robust in the numerous moderator analyses carried out, meaning they are not significantly influenced by many moderators. Significant differences for different subjects or age groups could not be identified. The types of digital tools and further variations in the implementation of digital support also made no statistically robust difference. One exception is the positive effect of teacher training.

Therefore, it can be assumed that the reported effects for the area of mathematical and science education in secondary schools represent a robust and generalizable estimate. The extent to which the findings can be generalized to other age levels (e.g., primary education), more sophisticated performance indicators (e.g., subject knowledge acquisition), or across cultural contexts is not clear from the meta-analysis.

**What makes this meta-analysis scientifically relevant?** This meta-analysis has a high degree of specificity due to its focus on mathematics and science in secondary education, while at the same time, it covers a broad spectrum of digital tools. This study is limited to classroom use of digital tools and not only examines effects on achievement but also effects on attitudes toward the subject at hand. This particular customization makes it possible to very consistently investigate relevant moderators and their effects for exactly this application area. Thus, the present meta-analysis has a special practical significance. Given the rapid development in this research area, the present meta-analysis provides a significant contribution to the synthesis of current findings.

**How methodologically reliable are the findings?** The transparency and justification of the methodological approach meets the standards criteria of common requirement guides (e.g. APA Meta-Analysis Reporting Standards) to a high degree. In particular, the areas of coding and analysis of the findings are excellently documented. More detailed information on the methodological assessment can be found in the rating sheet.

**CONCLUSION FOR CLASSROOM PRACTICE.** This meta-analysis clearly demonstrates that using digital tools in the classroom pays off. The positive effects of their use are evident, both in terms of achievement and attitudes toward science and mathematics subjects. The effects on achievement are robustly demonstrated for different subjects and across different ages. Large effects are particularly evident with software that dynamically visualize and simulate mathematical relationships, such as GeoGebra math software. Moreover, the results highlight the importance of appropriate teacher training for the successful use of digital tools in the classroom (see example study).

**EXAMPLE STUDY**

The study by Frailich, Kesner, & Hofstein (2009) shows the potential of digital tools in combination with targeted teacher training. In this study, tenth grade students should try to gain a better understanding of chemical bond structures. In the experimental condition, a website was provided, which included structured materials-consisting of visual modeling of chemical bonds and their structures. The teachers in this group first participated in a preparatory course for using the website. The 161 students in the experimental group worked interactively in small groups of two to three on the website with four learning units on different chemical substances (metals, ionic, & molecular compounds). The 93 students in the control group received instruction on the same content, only without the addition of the website. In the final knowledge test, learners in the experimental group performed significantly better than those in the control group ($g$ = 0.76). The findings of the study suggest that the students were better able to understand and learn the complex content through the use of the website.

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## LINKS.

To the meta-analysis from Hillmayr and colleagues (2020).

To the study example from Frailich and colleagues (2009).

## CITE AS.

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