

Finding Pathways to Effective Learning Environments: A Systematic Review of Online Learning for First Language Spelling Education

Katharina Simbeck^a, Nathalie Sellmeijer^b, Anne Schatz^c, Niels Pinkwart^d

^aHTW Berlin University of Applied Sciences, Germany, simbeck@htw-berlin.de, <https://orcid.org/0000-0001-6792-461X>

^bHTW Berlin University of Applied Sciences, Germany

^cHTW Berlin University of Applied Sciences, Germany

^dHumboldt-Universität zu Berlin, Germany, niels.pinkwart@hu-berlin.de, <https://orcid.org/0000-0001-7076-9737>

Abstract

Spelling and grammar are a priority in first language (L1) classrooms. Digital learning has increased significantly around the world, particularly as a result of the COVID-19 pandemic. While the range of online learning for spelling and grammar is very large, there is still no systematic review of the effectiveness of different features and platform characteristics in this area. This systematic literature review summarizes research on online learning platforms for L1 spelling and grammar instruction. We aim to synthesize what is known about online L1 learning environments and to infer the effectiveness and quality of a platform from its design, pedagogical approaches, or technologies used. Special attention is paid to the different features that can be implemented in such platforms. 49 relevant publications were included after a two-step screening process and application of inclusion and exclusion criteria. We found that digital L1 learning platforms are often described rather than evaluated in an experimental study. However, immediate feedback, repetition of tasks, and varying levels of difficulty were described as particularly effective for learning success. While digital learning platforms are widely used, adaptive or machine learning based methods were rarely found. The review suggests future work in adaptive learning environments for L1 learners and the integration of experimental studies.

Keywords: First-Language Learning; Online Learning; L1; Spelling; Grammar; Learning Platforms.

Introduction

Today, online learning is becoming increasingly important. In particular, the Covid-19 pandemic, which has led to school closures around the world, has significantly increased access to digital learning solutions. A study by the German Federal Statistical Office showed that the proportion of 10 to 15 year olds using learning platforms increased more than sevenfold from 8% to 59% in the first quarter of 2020 compared to 2019 (Statistisches Bundesamt, 2020).

Online learning is taking place in almost all subject areas and is intended to support school and university teaching, as well as corporate and individual learning. However, one subject that plays an important role in schools around the world is first language (L1) instruction, as learning spelling and grammar is essential for successful written and oral communication. For example, Rossiter (2021) states that learning basic grammatical rules and principles is necessary in order to express complex ideas with words (Rossiter, 2021). This is especially important in written communication because the reader usually cannot ask the writer for clarification or repetition. Therefore, the correct use of grammar and syntax, as well as vocabulary and spelling, is crucial to ensuring that the messages of a text are understood by the reader. A society that shares common rules of grammar and spelling is more inclusive and less divided into social classes based on level of education (Rossiter, 2021). Furthermore, knowledge of basic grammar and spelling is required for almost all jobs, so being able to express oneself grammatically and knowing basic spelling rules is essential when applying for a

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job. In addition, research has found a positive relationship between L1 and L2 writing, which again supports the importance of L1 skills (Ströbel et al., 2020). Therefore, this study focuses on online learning of L1 spelling and grammar.

While L1 online learning may seem a rather narrow field, it is actually very diverse: platforms can be structured and designed differently, target different groups of users, use different pedagogical approaches, and implement different technologies and tools, such as learning analytics or educational data mining. For example, while simply moving a test from paper-based to computer-based has no impact on user outcomes (Taylor et al., 1999), digital learning platforms with different features, designs and gamification elements can strongly influence the user's learning experience. However, a large proportion of the learning platforms available online are not scientifically validated (Knopf, 2016). Scientific research in this area, on the other hand, often focuses on the presentation of a single platform and its measured effectiveness. This research therefore aims to synthesize knowledge about online L1 learning from around the world and to infer the effectiveness and quality of a platform from its design, target group, pedagogical approaches, or technologies used. There is also a special focus on personalized and adaptive learning, as adaptive learning research is well advanced and there are many technical possibilities for implementation. During our review, we intend to answer the following research questions

RQ 1: What features are implemented in digital learning environments used for the acquisition of L1 spelling and grammar skills?

RQ 2: Which features of digital learning environments for the acquisition of L1 spelling and grammar skills have proven to be effective?

RQ 3: How widespread are features that support personalized or adaptive learning?

The review is structured as follows: first, section 1 presents the methodological approach. This includes the selection of databases, search terms, and the criteria that led to the inclusion and rejection of a paper. The results are divided into qualitative and quantitative results in section 2. The quantitative results provide an overview of selected characteristics of all papers. The qualitative results deal with the content of the papers. The papers that present a learning platform are described in terms of their method, the features used, and their results. At the end of the review in section 3, the results are discussed and interpreted.

1. Method

The following section describes the procedure of this literature review. First, we present the databases used, the search period, and the search terms. We then present the inclusion and exclusion criteria. In addition, we describe the further attempts we made to find relevant articles. This includes screening relevant journals as well as manually adding content from book chapters that cannot be found digitally. Finally, in this section we present a flowchart showing the number of papers in each step of the screening process.

To create the literature review, we searched three databases: Google Scholar, learntechlib, and ieeexplore. Considerations of digital learning systems have been around for more than 20 years, so we did not limit our search in time. The databases were searched in July and August 2021.

A total of 14 search terms were defined, 7 in German and 7 in English, as shown in Table 1. They each consist of two parts. The first part contains keywords related to spelling and grammar skills. We have chosen to include spelling and orthography because these are terms commonly used to describe these issues in schools. The second part is about digital learning environments.

Table 1. Search Terms.

Language	Search term
DE	(rechtschreibung OR orthografie) AND („digitale lernumgebung“ OR lernplattform OR lernsoftware)
DE	deutschunterricht AND „digital* rechtschreibung“
ENG	(spelling OR orthography) AND (“digital learning environment” OR “online learning” OR “virtual learning environment”)
ENG	“german lesson” AND “digital spelling”

Since there are no German-language papers in the learntechlib and ieeexplore databases, the German search terms were only applied to Google Scholar. Inclusion and exclusion criteria were defined to objectively assess whether a publication was included in the search, and are detailed in Table 2.

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Table 2. Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
L1 learning	L2 learning / English as a foreign language (EFL) / second language learning
Papers written in English or German	Papers written in other languages
All target languages	-
Spelling, Grammar, Vocabulary, Phonetics	Essay-writing, reading, theater books
Doctoral theses	Bachelor or master theses
Digital learning regarding L1	Digital learning in general, without relation to L1 learning
Platforms and their features	Educational Design / Pedagogical Settings
	Tools and plugins to use in digital learning settings, such as automated error tagging

Only papers that examine digital learning platforms, environments or software in first language classrooms will be included. Any content dealing with second language learning is not included. Also, only papers written in English and German are included, but all languages studied are included. The skills studied in the papers must be spelling, vocabulary, grammar, or phonetics. Other content taught in first language classes (e.g., essay writing, reading, drama, literature, and interpretation) is not included. Similarly, bachelor's and master's theses are excluded, but doctoral theses are included.

In addition to extracting the results from the search terms and databases, we made further attempts to find relevant publications. To do this, we used the results of the database search after the end of the second screening to find out which journals appeared most frequently in our results. From all journals with at least two publications in our results, we again screened all publications from the last five years (2017-2021). In addition, we manually added a few more papers. These included papers in non-digital edited volumes and articles by authors referenced in the other papers.

During our review of the results, there was one outlier. One paper presented a language learning app for children with a migration background (Gebele & Kaleta, 2019; Neumann & Stahl, 2017). Strictly speaking, language instruction for children with a migrant background cannot be counted as L1, since the children have a different first language. However, these children are of course part of the first language class. Furthermore, the applications are also used in this context - especially to support the teachers in dealing with the heterogeneity of the classes. Therefore, we decided to include this case.

Figure 1 shows the flowchart of our screening process.

At the end of the screening process, 49 papers were included in the literature review. These 49 papers were clustered according to different dimensions in order to answer the research questions. These include the language taught, the competencies, and the user group, as well as the methodology implemented in the studies. In addition, categories of features were derived from the results and the studies were clustered into these categories based on the features implemented. The results of the studies are also considered.

2. Results

The following section describes the results of this literature review. We will first provide a quantitative overview of the included work and then describe it in more detail.

2.1. Quantitative results

Although we were only able to include papers written in German and English, the papers in our results discussed digital L1 learning of many different languages. Figure 2 shows the distribution of languages. The vast majority of results examine learning platforms in German. 8 other studies look at L1 English lessons. Other languages appear only 1-2 times.

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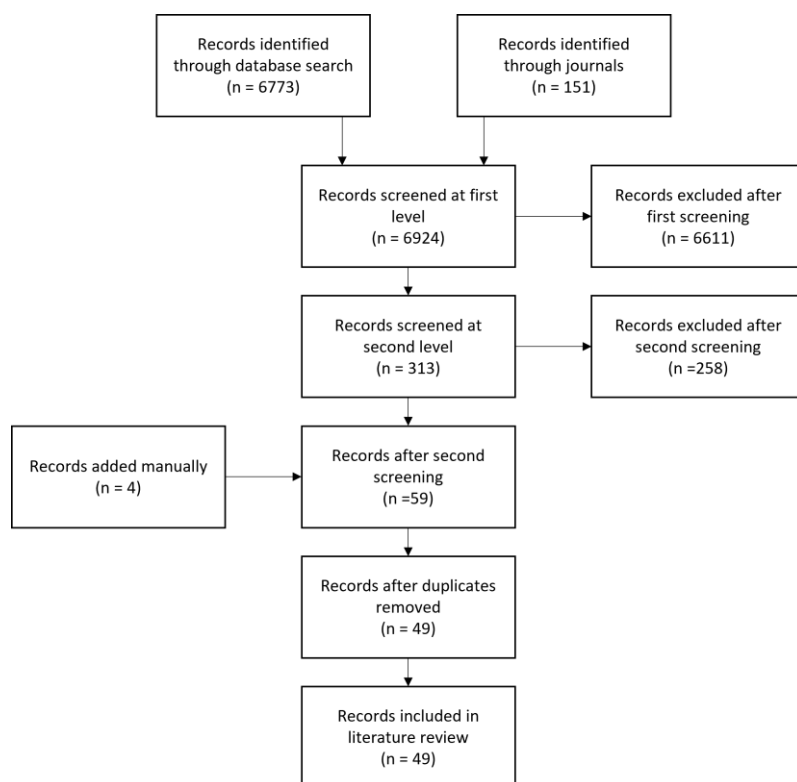


Figure 1. Flow Chart of the screening process.

Since we are dealing with first language instruction, most of the papers consider younger school children. However, there are some differences in the target group considered by the papers. Figure 3 shows the different target groups. While primary and secondary schools are the majority of target groups studied, there is also research focusing on children from migrant backgrounds and children with special needs, for example children diagnosed with ADHD, dyslexia or other learning difficulties. Few papers also examine learning environments with pre-service teachers as the target group, for example, interview studies discussing pedagogical concepts of L1 instruction.

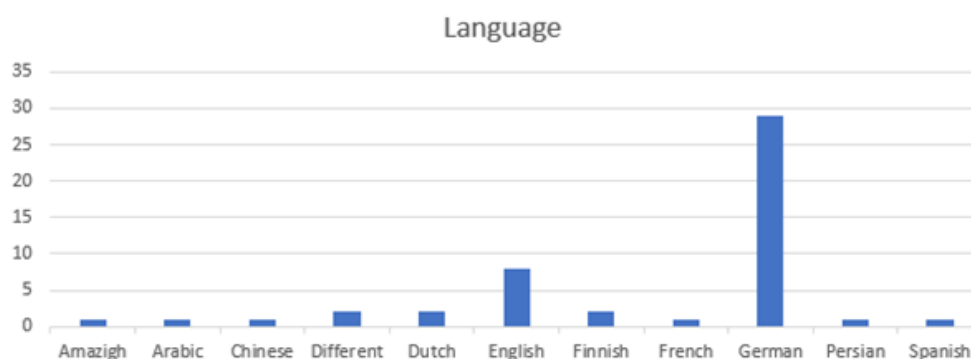


Figure 2. Distribution of languages in reviewed literature.

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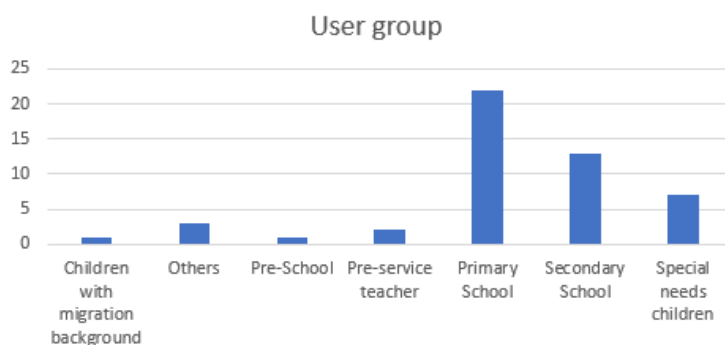


Figure 3. User groups in reviewed literature.

Most platforms and research specialize in a particular skill to be learned through digital systems. Figure 4 shows the skills studied. Based on the search terms, most of the results are related to spelling skills. These learning platforms offer exercises in capitalization, punctuation, or phonetic-letter mapping. Other skills include learning the alphabet or new words (vocabulary) and phonetic transcription.

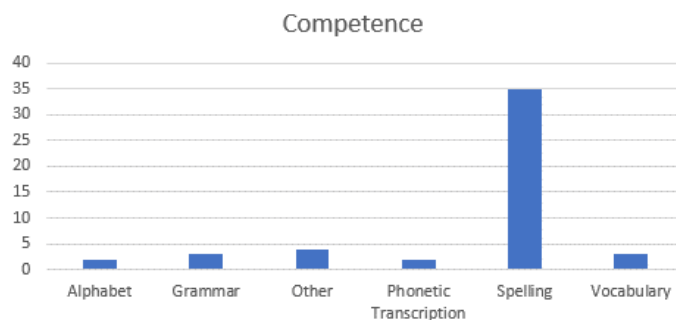


Figure 4. Competencies studied in reviewed literature.

2.2. Qualitative results

In the following, we discuss the qualitative findings of the 49 papers that present educational software, platforms, or apps and examine their effectiveness. There are papers that propose and present learning platforms, apps or software for L1 learners, as well as research that evaluates the effectiveness of technology-integrated instruction, for example through experimental studies with a control and treatment group. Table 3 shows the methods used in these 49 papers. 16 papers present an existing or planned software, application or learning platform. This includes an explanation of the pedagogical background and pedagogical design, the goal of the software, and key features. A total of 12 papers conducted an experimental study to investigate the effectiveness of the platform. For this purpose, control and intervention groups were formed. In most cases, the control group was taught with regular school lessons, while the intervention group used the presented platform or software in addition. Statistical measures were then used to determine whether the two target groups differed in their scores and whether these differences were significant. Paired sample t-tests, among others, were used for this purpose. Some articles assessed student learning using more specific measures, such as the Kaufmann Test of Educational Achievement (KTEA). (Anderson & Kieran, 2016) or the Salzburg Reading and Writing Test II (Schöfl, 2016). Other authors did not create a control and intervention group but studied the same group in pre- and post-tests. Meanwhile, an application or learning platform was used. In one case, an individual's development was studied as an example, and improvements were measured in pre- and post-tests. (Anderson & Kieran, 2016) Twelve studies used qualitative methods: Interview studies surveyed users after using a product, others surveyed teachers or parents. One study observed users' interactions with the learning platform, and two others qualitatively analyzed user-generated results. There were also two literature reviews and two papers that used completely different methods.

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Table 3. Methods of presenting educational software.

Method	Count	Papers
Presentation of platform, software, or app	16	(Aspalter et al., 2017; Beißwenger & Meyer, 2018, 2020; Beiswanger, 2019; Ebner et al., 2016; Ebner et al., 2018; Eckle & Knopf, 2016; Juhani Lyytinen et al., 2021; Jung et al., 2016; Knopf & Brodt, 2016; Köller, 2011; Mangina et al., 2018; Müller, 2008, 2017; Schröter & Kochan, 2001; Wang, 2019)
Experimental study: pre- and posttest for treatment and control group	12	(Berkling, 2017; Berkling Kay, Pflaumer Nadine, Lavalley Rémi., 2015; Ghysels & Haelermans, 2018; Potocki et al., 2021; Pröbl, 2016; Ronimus et al., 2020; Schöfl, 2016; Scholten-Theuerzeit & Görlich, 2007; Simpson & Park, 2013; van Weerdenburg et al., 2019; Warren et al., 2008; Zare et al., 2020)
Pre- and posttest of one group or one person (no control group)	6	(Anderson & Kieran, 2016; Berkling et al., 2015; Berkling & Kermes, 2020; Rösch et al., 2016; Tan Geok Tin et al., 2018; Titterington & Bates, 2018)
Qualitative analysis or comparison of the user results (e.g., written text)	3	(Berndt, 2005; Cordero et al., 2018; Diekmannshenke, 1999)
Qualitative user interviews	4	(Bahr & Langenberg, 2009; Scholten-Theuerzeit & Görlich, 2007; Schwaiger et al., 2018; Tazouti et al., 2019)
Qualitative interviews of teachers or parents	3	(Beißwenger & Meyer, 2020; Maskati et al., 2021; Zou, 2006)
User observation	3	(Krammer et al., 2006; Maskati et al., 2021); (Winkler et al., 2015)
Literature review	2	(Majid & Salam, 2021; Parmaxi & Demetriou, 2020)
Other methods	2	Kline & McCartney, 2018; Winkler et al., 2015

When introducing and investigating a new learning platform or software, it is of interest how the pedagogical goals are to be achieved. The range of features and structure of learning platforms, applications and software is very broad. In the following, we will examine the features from five perspectives, each of which describes different aspects of a learning platform: user interface, instructional features, gamification, reporting, and other (Table 4). The first perspective relates to the user interface and the presentation of learning content. In this category, eight papers have incorporated narratives, such as a mascot, a teaching agent, or a consistent storyline. Many platforms incorporate multimedia elements, including visual components such as graphics and animations, and auditory components such as voice output to read words aloud. One paper advocates allowing users to record their own voice and play it back on the platform to detect pronunciation errors. Three applications feature a touchscreen interface, and two papers describe a 3D learning environment. Neumann and Stahl (2017) integrate push notifications to remind users. Ebner et al. (2018) offer the possibility to publish texts within the class.

From an instructional perspective, the most common feature is immediate constructive feedback, which is included in 18 papers. Nine papers describe automatic repetition of tasks that a user has done incorrectly. The use of word lists, intelligent dictionaries, and spell checkers is found in 10 papers. Different levels of difficulty are offered in 12 papers, and the level of difficulty is individually adjusted in eight papers. Less common are suggestions for further tasks, suggestions for alternative spellings of words, or the display of help and corrections. Five papers consider the potential of augmented and virtual reality, and only one paper writes about performance prediction. (Ebner et al., 2016).

A gamification perspective is taken in 21 papers. Many use gamification elements such as a progress bar, points, badges, rewards, life and death. Seven papers are multi-user games that promote social collaboration among users in addition to language skills.

A reporting perspective is included in 10 papers. The reporting modules can either be viewed by the users themselves, e.g. as dashboards, or as diagnostic modules that can be viewed by parents and teachers. Other features include suitability for blended learning concepts or adaptations according to national curricula.

In several categories there are features that can also be implemented adaptively. This is especially true for adaptive adjustment of difficulty. (Ghysels & Haelermans, 2018; Jung et al., 2016; Krammer et al., 2006; Pröbl, 2016; Ronimus et al., 2020) or adaptive feedback (Berkling & Kermes, 2020). A diagnostic module has also been implemented adaptively. (Diekmannshenke, 1999).

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Table 4. Features in digital learning platforms.

Feature	Count	Papers
User Interface / Representation		
Narratives, such as storyline, narrator	8	(Anderson & Kieran, 2016; Kline & McCartney, 2018; Maskati et al., 2021; Scholten-Theuerzeit & Görlich, 2007; Schröter & Kochan, 2001; van Weerdenburg et al., 2019; Wang, 2019; Warren et al., 2008)
Multimedia (voice output, visuals, animations)	20	(Anderson & Kieran, 2016; Beiswanger, 2019; Berkling et al., 2015; Berkling, 2017; Berkling Kay, Pflaumer Nadine, Lavalley Rémi., 2015; Cordero et al., 2018; Eckle & Knopf, 2016; Juhani Lyytinen et al., 2021; Krammer et al., 2006; Maskati et al., 2021; Pröbl, 2016; Ronimus et al., 2020; Schröter & Kochan, 2001; Tan Geok Tin et al., 2018; Tazouti et al., 2019; Titterington & Bates, 2018; Wang, 2019; Warren et al., 2008; Zare et al., 2020; Zou, 2006)
Upload and play own audio recording	1	(Fey & Matthes, 2017)
Touch-screen interface	3	(Cordero et al., 2018; van Weerdenburg et al., 2019; Wang, 2019)
3D Learning environment	2	(Tazouti et al., 2019; Warren et al., 2008)
Push-notifications	1	(Neumann & Stahl, 2017)
Opportunity to share results with class	2	(Ebner et al., 2016; Ebner et al., 2018)
Chat function	1	(Rösch et al., 2016)
Instruction features		
Immediate, corrective feedback	18	(Anderson & Kieran, 2016; Aspalter et al., 2017; Berkling et al., 2015; Berkling, 2017; Berkling & Kermes, 2020; Berkling Kay, Pflaumer Nadine, Lavalley Rémi., 2015; Ebner et al., 2016; Ebner et al., 2018; Ghysels & Haelermans, 2018; Müller, 2008; Potocki et al., 2021; Ronimus et al., 2020; Scholten-Theuerzeit & Görlich, 2007; Schröter & Kochan, 2001; Titterington & Bates, 2018; Wang, 2019; Warren et al., 2008; Zare et al., 2020)
Repetition of incorrectly answered tasks	9	(Anderson & Kieran, 2016; Berkling et al., 2015; Berkling, 2017; Berkling Kay, Pflaumer Nadine, Lavalley Rémi., 2015; Ghysels & Haelermans, 2018; Juhani Lyytinen et al., 2021; Müller, 2008; Pröbl, 2016; Zare et al., 2020)
In-game dictionary	4	(Anderson & Kieran, 2016; Ebner et al., 2016; Ebner et al., 2018; Köller, 2011)
Word list	2	(Anderson & Kieran, 2016; Wang, 2019)
Spell-checking, Thesaurus	4	(Berndt, 2005; Ebner et al., 2016; Ebner et al., 2018; Zou, 2006)
Pre-test	4	(Diekmannshenke, 1999; Jung et al., 2016; Köller, 2011; Simpson & Park, 2013)
Different levels	12	(Beißwenger, 2020; Beißwenger & Meyer, 2018, 2020; Berkling et al., 2015; Berkling, 2017; Berkling Kay, Pflaumer Nadine, Lavalley Rémi., 2015; Fey & Matthes, 2017; Potocki et al., 2021; Pröbl, 2016; Schöfl, 2016; Titterington & Bates, 2018; Zare et al., 2020)
Individual adjustment of the difficulty levels	8	(Berkling & Kermes, 2020; Ghysels & Haelermans, 2018; Jung et al., 2016; Krammer et al., 2006; Pröbl, 2016; Ronimus et al., 2020; Schöfl, 2016; Simpson & Park, 2013)
Recommendation	2	(Ebner et al., 2016; Ebner et al., 2018)
Suggestions for alternative word spellings	3	(Berndt, 2005; Ebner et al., 2016; Ebner et al., 2018)
Display of mistakes and corrections	1	(Müller, 2017)
Help	1	(Warren et al., 2008)
Performance predictions	1	(Ebner et al., 2016)
Pedagogical selection of words suitable for children	1	(Schwaiger et al., 2018)
AR/ VR	5	(Eckle & Knopf, 2016; Majid & Salam, 2021; Mangina et al., 2018; Maskati et al., 2021; Parmaxi & Demetriou, 2020)

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Gamification		
Game-based learning	18	(Beißwenger, 2020; Beißwenger & Meyer, 2018, 2020; Berkling et al., 2015; Berkling, 2017; Berkling Kay, Pflaumer Nadine, Lavalley Rémi, 2015; Eckle & Knopf, 2016; Jung et al., 2016; Köller, 2011; Krammer et al., 2006; Majid & Salam, 2021; Mangina et al., 2018; Müller, 2017; Pröbl, 2016; Rösch et al., 2016; Schwaiger et al., 2018; Winkler et al., 2015; Zare et al., 2020)
Serious game	3	(Berkling & Kermes, 2020; Ronimus et al., 2020; Tazouti et al., 2019)
Multi-user gameplay	7	(Beißwenger, 2020; Beißwenger & Meyer, 2018, 2020; Jung et al., 2016; Rösch et al., 2016; Warren et al., 2008; Winkler et al., 2015)
Progress Bar	5	(Berkling et al., 2015; Berkling, 2017; Berkling Kay, Pflaumer Nadine, Lavalley Rémi, 2015; Fey & Matthes, 2017; Wang, 2019)
Reward system	8	(Beißwenger, 2020; Beißwenger & Meyer, 2018, 2020; Beiswanger, 2019; Berkling et al., 2015; Berkling, 2017; Berkling Kay, Pflaumer Nadine, Lavalley Rémi, 2015; Pröbl, 2016; Schwaiger et al., 2018)
Multi-agent	1	(Tazouti et al., 2019)
Points, Badges	8	(Beißwenger, 2020; Beißwenger & Meyer, 2018, 2020; Berkling et al., 2015; Berkling, 2017; Berkling Kay, Pflaumer Nadine, Lavalley Rémi, 2015; Fey & Matthes, 2017; Müller, 2017)
Fun death, lives	3	(Berkling et al., 2015; Berkling, 2017; Berkling Kay, Pflaumer Nadine, Lavalley Rémi, 2015)
Reporting		
Dashboard	6	(Ebner et al., 2016; Ebner et al., 2018; Jung et al., 2016; Müller, 2017; Schöfl, 2016; Scholten-Theuerzeit & Görlich, 2007)
Reporting and diagnostics module	6	(Aspalter et al., 2017; Diekmannshenke, 1999; Ebner et al., 2016; Ebner et al., 2018; Ghysels & Haelermans, 2018; Mangina et al., 2018)
Other		
Blended Learning	4	(Beißwenger, 2020; Beißwenger & Meyer, 2018, 2020; Berkling & Kermes, 2020)
Curriculum based content	2	(Knopf & Brodt, 2016; Warren et al., 2008)

A rough overview of the results of the reviewed papers is given in Table 5. A total of 16 papers investigated the effectiveness of the presented application, software or platform with statistical tests. Of these, 14 showed a significant improvement, either for the treatment group or, if there was no control and treatment group, for the post-test. Only 2 papers showed no improvement. Positive qualitative results were reported in 17 papers. These include good ratings of the software in user surveys or teacher interviews, an improvement in motivation and engagement shown in user observations, or the positive evaluation of user outcomes in a qualitative comparison with outcomes from traditional teaching. 15 papers presented only one educational software or application and therefore did not present any results.

Table 5. Results of control treatment experiments.

Results	Count	Papers
Statistically significant improvement in comparison with the control group or pretest	14	(Anderson & Kieran, 2016; Berkling et al., 2015; Berkling, 2017; Ghysels & Haelermans, 2018; Potocki et al., 2021; Pröbl, 2016; Rösch et al., 2016; Scholten-Theuerzeit & Görlich, 2007; Simpson & Park, 2013; Tan Geok Tin et al., 2018; Titterington & Bates, 2018; van Weerdenburg et al., 2019; Warren et al., 2008; Zare et al., 2020)
No statistically significant improvement in comparison with the control group	2	(Ronimus et al., 2020; Schöfl, 2016)
Qualitative improvement (e.g., in questionnaire, improvement of motivation and engagement, or manual analysis) without statistical measurement	17	(Beißwenger & Meyer, 2020; Beiswanger, 2019; Berkling Kay, Pflaumer Nadine, Lavalley Rémi, 2015; Berndt, 2005; Cordero et al., 2018; Ebner et al., 2018; Juhani Lyytinen et al., 2021; Kline & McCartney, 2018; Krammer et al., 2006; Maskati et al., 2021; Parmaxi & Demetriou, 2020; Pröbl, 2016;

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		Scholten-Theuerzeit & Görlich, 2007; Schwaiger et al., 2018; Tazouti et al., 2019; Winkler et al., 2015; Zou, 2006)
No result, just proposal	15	(Aspalter et al., 2017; Beißwenger, 2020; Beißwenger & Meyer, 2018; Diekmannshenke, 1999; Ebner et al., 2016; Eckle & Knopf, 2016; Fey & Matthes, 2017; Jung et al., 2016; Knopf & Brodt, 2016; Köller, 2011; Mangina et al., 2018; Müller, 2008, 2017; Rösch et al., 2016; Schröter & Kochan, 2001; Wang, 2019)
Other	3	(Bahr & Langenberg, 2009; Berkling & Kermes, 2020; Majid & Salam, 2021)

3. Discussion

After presenting the results, we will interpret and summarize them in the following sections in order to draw conclusions and answer the research questions defined at the beginning of the review. In addition, we will present the limitations of the papers and the review process, as well as implications for future research.

Our research questions focus on the features of digital learning environments:

RQ 1. What features are implemented in digital learning environments for the acquisition of L1 spelling and grammar skills?

We divided the features in our findings into different categories: user interface and presentation (1), instructional and technical features (2), gamification (3), reporting (4), and other (5). Most digital learning platforms work with different types of multimedia, such as visuals, animations or voice output. Commonly used learning features are immediate feedback, repetition of incorrect tasks, and difficulty levels. In addition, many papers implemented game-based learning, where a reward system such as points and badges was most often used. There were only a few platforms that implemented some kind of reporting module.

The second research question focused on the evaluation of features:

RQ 2. What features in digital learning environments have been shown to be effective for the acquisition of L1 spelling and grammar skills?

Most of our findings presented and described educational software, platforms, or applications. However, out of 49 papers, only 18 conducted an experimental study with pre- and post-tests, and only 12 also had a treatment and control group. The other papers mainly described their software or conducted a qualitative analysis through user interviews, observation, or comparison of results. Although there are some experimental studies, we conclude that the majority of research on online L1 learning is descriptive.

RQ 3: How widespread are features that support personalized or adaptive learning?

Of particular interest for the development of digital learning platforms and the core area for the use of personalized and adaptive learning is the area of instructional features (Table 4). This area is of particular interest because much of the differentiation in the learning experience takes place here. While the technical possibilities for adaptive learning are already being explored by researchers, many L1 learning platforms do not yet incorporate these techniques. A striking aspect of the analysis and review of features is that overall there are few platforms that are adaptive or use technologies from the field of educational data mining. Adaptive platforms are defined by Paramythis and Loidl-Reisinger as adaptive when they are "capable of: monitoring the activities of its users; interpreting these activities on the basis of domain-specific models; inferring user requirements and preferences from the interpreted activities, representing these appropriately in associated models; and finally, acting on the available knowledge about its users and the subject matter at hand to dynamically facilitate the learning process" (Paramythis & Loidl-Reisinger, 2003). Some of the listed features can be implemented adaptively. These include performance prediction, recommendation, individual adjustment of difficulty, and a diagnostic module. However, the actual implementation or presentation of adaptive learning is only described in nine papers (Berkling & Kermes, 2020; Diekmannshenke, 1999; Ghysels & Haelermans, 2018; Jung et al., 2016; Krammer et al., 2006; Pröbl, 2016; Ronimus et al., 2020; Schöfl, 2016; Simpson & Park, 2013).

The most frequently used instructional features are immediate feedback, different levels and individual adaptation to the user, and repetition of incorrectly solved tasks. Table 6 is an integration of features and results. Included are all features from the Instruction category. The columns define three types of results: statistically significant improvement, no statistically significant improvement, and qualitative improvement. Only papers that reported results are included in this table.

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Table 6. Integration of instruction features and results.

Feature	Statistically significant improvement in comparison with the control group or pretest	No statistically significant improvement in comparison with the control group	Qualitative improvement (e.g., in questionnaire, improvement of motivation and engagement, or manual analysis without statistical measurement)
Immediate, corrective feedback	18	1	2
Repetition of incorrectly answered tasks	9	0	2
In-game dictionary	4	0	1
Word list	2	0	0
Spell-checking, Thesaurus	0	0	4
Pre-test	4	0	0
Different levels	12	0	3
Individual adjustment of the difficulty levels	8	2	1
Recommendation	0	0	2
Suggestions for alternative word spellings	0	0	3
Display of mistakes and corrections		No results	
Help	1	0	0
Performance predictions		No results	
Pedagogical selection of words suitable for children	0	0	1
AR/ VR	0	0	2

It can be seen that the four most studied features also showed many statistically significant and qualitative improvements in the results. Furthermore, some of the features were not tested in an experimental study at all, but only in the descriptions of the learning platforms. In this context, publication bias should be taken into account. Studies that do not achieve statistically significant results are published much less frequently than those that do. Therefore, only cautious conclusions can be drawn from the frequency of significant / non-significant results.

When interpreting the results, differences between German-language publications (n=20) and English-language publications (n=29) are also noticeable. When comparing the methodology, there is a clear difference, as German publications are mainly found as presentations and descriptions of platforms (n German = 11, n English = 5) and English publications are mainly found in experimental studies with pre- and posttests (n German = 3, n English = 15). When comparing the features used, multimedia features are included much more often in English language studies than in German language studies (n German = 4, n English = 16). The features immediate, corrective feedback and repetition of incorrectly answered tasks are also presented more often in English language publications. The entire gamification section, on the other hand, has consistently found more space in German-language publications. It is possible that these differences are related to the fact that in German-speaking countries, platforms with gamification or learning games are presented, while in English-language studies, standard features of learning platforms are compared with each other and experimental studies are conducted.

In general, despite the widespread use of learning platforms for language acquisition around the world, detailed research on the effectiveness of these platforms is still in its infancy. While there is a great deal of research on such platforms, much of it does not go beyond description. There are few studies with control and intervention groups, and there is a complete lack of individual research on the features implemented in these platforms. In addition, there is a large gap between the many research findings in the field of learning analytics and adaptive learning: the transfer to practice has not yet taken place in many cases.

Nevertheless, from the review of the literature, we were able to identify some features that stand out as positive influences. These are immediate feedback, multiple levels, individualization, and repetition of incorrect exercises.

3.1. Limitations

The biggest limitation of our review process is that we could only include papers written in English and German. This introduces a bias, as we have mainly papers that refer to the first languages German and English. It is conceivable that other approaches to digital learning environments have been found in other languages, especially if they are languages

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with a different script (for example, Chinese or Arabic). There may also be a fundamental bias in this area, as first language learning platforms may be published primarily in that first language. This makes it difficult to share research across languages. It would be interesting to find out which features of learning platforms are effective in all languages and which differ from language to language.

Another limitation may be that in many cases the results of an evaluation of learning platforms cannot be related to individual features, but only to the platform itself. This means that if a platform is found to be effective and implements a number of different features, it is not possible to say which of the features were responsible for the positive evaluation of the platform. This could be remedied by a study design that compares different features or interventions within the same platform (i.e., with the same language, user group, and competence). This can be done in the context of A/B testing and then statistically evaluated.

When comparing results, publication bias must always be taken into account. Papers with statistically significant results are published much more often than papers without significant results. This makes it difficult to compare significant and non-significant results. Therefore, comparing the results does not allow us to draw accurate conclusions about the effectiveness of features for users. Therefore, it is better to compare the features with each other, and possibly find out if there are a particularly large number of publications that use a particular feature, as well as publications that compare features in their work.

3.2. Implications for future research and practice

Our review leads to some implications for further research. First, further research should be conducted to systematically test and evaluate features of L1 learning platforms with a large group of users. In this way, it can be compared which technical implementations are particularly suitable for supporting users in learning their first language. Furthermore, it should be investigated whether and to what extent the results differ for different target groups (e.g. grade level, type of school or children with special needs).

In general, there is still a great potential for adaptive learning platforms for L1 learning. There is still little research in this area, although the technical possibilities of adaptive learning are being investigated in many studies. It would also be interesting to compare digital and adaptive learning platforms to find out how effective adaptive learning is for first language learning. Furthermore, more standardized criteria could be developed to measure the quality of platforms. By integrating these issues, research can go a step further and consider the field of digital learning of L1 languages in a holistic and integrated way.

Further implications for practice are that the use of online platforms for L1 learning is effective, especially if they implement immediate feedback, task repetition, or personalized adaptations. Practitioners should also be encouraged to implement learning analytics and adaptive learning in their platforms, as these have been extensively researched and shown to be effective in many areas of learning.

Conclusions

This paper presents a systematic review of digital learning environments for first language learning. In a total of 49 papers, we find that many papers deal with platforms for L1 instruction, but several do not go beyond a descriptive approach. Evaluations of the platforms show that most are positively evaluated and are particularly effective in implementing multiple levels, immediate corrective feedback, and task repetition. However, most platforms are digital only and do not yet offer adaptive features.

In summary, we see that many platforms are described using a large number of features, but at the same time experimental studies to compare the effectiveness of specific features are not yet a focus of research. Comparison is therefore difficult, not only because features are not evaluated separately, platforms focus on different user groups and competencies, but also because different languages may have different difficulties for their learners that need to be addressed. But especially as personalized or adaptive learning features are increasingly implemented in learning platforms, specific statistical evaluations are needed.

References

Anderson, C., & Kieran, L. (2016). Technology and Language Arts: A good recipe for one adolescent girl! In G. Chamblee & L. Langub (Eds.), SITE 2016 (pp. 2746–2755). Association for the Advancement of Computing in Education (AACE). <https://www.learntechlib.org/p/172080/>

Finding pathways to effective learning environments: A Systematic Review of online learning for first language spelling education

Simbeck, K., Sellmeijer, N., Schatz, A., Pinkwart, N.

- Aspalter, C., Edtstadler, K., & Martich, S. (2017). Recht-/schreibdidaktische Überlegungen für den Einsatz der Internetplattform IDeRBlog. R&E-SOURCE, 1–15. <http://journal.ph-noe.ac.at/index.php/resource/article/download/368/420>
- Bahr, J., & Langenberg, H. (2009). Übungsprogramme zur Grammatik im Internet: Über ihre Nützlichkeit für eigenständige Lernprozesse. http://www.linse.uni-due.de/files/PDF_in_Katalog/publikationen/ESEL/bungsprogramme_Grammatik_im_Internet_LINSE.pdf
- Beißwenger, M. (2020). Zum Lernen verlocken: Erfahrungen mit einem online-gestützten Planspiel zur Reflexion über Rechtschreibung und Grammatik in der Sekundarstufe I. Duepublico. https://duepublico2.uni-due.de/servlets/MCRFileNodeServlet/duepublico_derivate_00074174/OBST_96_Beisswenger_Meyer_135.pdf
- Beißwenger, M., & Meyer, L. (2018). Ortho & Graf: ein Wiki-basiertes Planspiel zur Förderung von Rechtschreibkompetenzen in der Sekundarstufe II. In S. Gailberger & F. Wietzke (Eds.), Lernsoftware als Unterstützung binnendifferenzierten Rechtschreibunterrichts: Deutschunterricht in einer digitalisierten Gesellschaft. Unterrichtsanregungen für die Sekundarstufen (pp. 296–330). https://www.uni-due.de/imperia/md/images/germanistik/beisswenger/beisswengermeyer_orthoundgraf.pdf
- Beißwenger, M., & Meyer, L. (2020). Gamification als Schlüssel zu „trockenen“ Themen? Beobachtungen und Analysen zu einem webbasierten Planspiel zur Förderung orthographischer Kompetenz. In K. Beckers & M. Wassermann (Eds.), Wissenskommunikation im Web. Sprachwissenschaftliche Perspektiven und Analyse (pp. 203–223).
- Beiswanger, C. (2019). Lautarium. Lernen Und Lernstörungen, 8(3), 193. <https://econtent.hogrefe.com/doi/10.1024/2235-0977/a000275>
- Berkling, K. (2017). Phontasia: A phonics game for German and its effect on orthographic skills-first corpus explorations. https://www.researchgate.net/profile/Kay-Berkling/publication/321099544_Phontasia_A_phonics_game_for_German_and_its_effect_on_orthographic_skills-first_corpus_explorations/links/5a30f843a6fdccbf7ef18362/Phontasia-A-phonics-game-for-German-and-its-effect-on-orthographic-skills-first-corpus-explorations.pdf
- Berkling, K., & Kermes, H. (2020). Learning to take the next step: Knowledge acquisition of orthographic patterns in serious games with immediate feedback.
- Berkling, K., Pflaumer, N., & Coyplove, A. (2015). Phontasia—a game for training german orthography (I). INTERSPEECH 2015: Show & Tell Contribution. https://www.isca-speech.org/archive_v0/interspeech_2015/papers/i15_1874.pdf
- Berkling Kay, Pflaumer Nadine, Lavalley Rémi. (2015). German phonics game using speech synthesis-a longitudinal study about the effect on orthography skills. https://www.researchgate.net/profile/Anton-Batliner/publication/335110484_Speech_and_Language_Technology_in_Education_SLaTE_2015_Proceedings_of_the_6th_International_ISCA_Workshop/links/60b4a8c645851557baaf73a9/Speech-and-Language-Technology-in-Education-SLaTE-2015-Proceedings-of-the-6th-International-ISCA-Workshop.pdf#page=179
- Berndt, E.-B. (2005). Rechtschreibkompetenz als Korrekturkompetenz–Förderung mit digitalen Rechtschreibhilfen. In H.-W. Huneke (Ed.), Schriftenreihe der Pädagogischen Hochschule Heidelberg: Vol. 45. Geschriebene Sprache: Strukturen, Erwerb, didaktische Modellbildungen (pp. 145–161). Mattes. http://www.mattes.de/buecher/paedagogische_hochschule/978-3-930978-71-7.pdf#page=145
- Cordero, K., Nussbaum, M., Ibasetta, V., Otaíza, M. J., & Chiuminatto, P. (2018). Read, write, touch: Co-construction and multiliteracies in a third-grade digital writing exercise. Journal of Computer Assisted Learning, 34(2), 162–173. https://onlinelibrary.wiley.com/doi/full/10.1111/jcal.12224?casa_token=SzTePz7NC00AAAAA%3AwPAxRk4nU7gHiBAmfWBSOWKWAgHYOhT7cEfGtczq2eaG_IwUI8wbBfaSmSh6UfvUjURPz0qz5ceqSE
- Diekmannshenke, H. (1999). Der Einsatz von Lernsoftware in Unterricht und Studium Praxiserfahrungen und linguistische Betrachtungen. In Konfigurationen 5: Beiträge zur Linguistik und Methodik (pp. 71–81). <https://repozytorium.ukw.edu.pl/bitstream/handle/item/3078/diekmannshenke%20der%20einsatz%20von%20lernsoftware%20in%20unterricht%20und%20studium%20praxiserfahrungen%20und%20linguistische%20betrachtungen.pdf?sequence=1&isallowed=y>

Finding pathways to effective learning environments: A Systematic Review of online learning for first language spelling education

Simbeck, K., Sellmeijer, N., Schatz, A., Pinkwart, N.

- Ebner, M [Markus], Ebner, M [Martin], & Edtstadler, K. (2016). Learning Analytics and Spelling Acquisition in German - A First Prototype. In P. Zaphiris & A. Ioannou (Eds.), *International Conference on Learning and Collaboration Technologies* (Vol. 9753, pp. 405–416). Springer, Cham. https://doi.org/10.1007/978-3-319-39483-1_37
- Ebner, M [Markus], Edtstadler, K., & Ebner, M [Martin] (2018). Tutoring writing spelling skills within a web-based platform for children. *Universal Access in the Information Society*, 17(2), 305–323. <https://link.springer.com/article/10.1007/s10209-017-0564-6>
- Eckle, J., & Knopf, J. (2016). Mit digitalen Medien fit für den Schriftspracherwerb. In J. Knopf & U. Abraham (Eds.), *Deutsch digital: Theoretische Grundlagen und Implikationen für die Praxis/Theorieband* (25-29). Schneider Verlag Hohengehren. https://books.google.xn--de/books?hl=fr&lr=&id=_PZiEAAAQBAJ&oi=fnd&pg=PP1&dq=Mit+digitalen+Medien+fit+fr+den+Schriftspracherwerb+eckle+knopf&ots=mbdGBU3-Nn&sig=LhLO6cgUI2Qs9G3DMMDpTISUKiI&redir_esc=y#v=onepage&q=Mit%20digitalen%20Medien%20fit%20fr%20den%20Schriftspracherwerb%20eckle%20knopf&f=false-s51axg
- Fey, C.-C., & Matthes, E. (Eds.). (2017). *Das Augsburger Analyse- und Evaluationsraster für analoge und digitale Bildungsmedien (AAER). Grundlegung und Anwendungsbeispiele aus interdisziplinärer Perspektive.* <https://www.fachportal-paedagogik.de/literatur/vollanzeige.html?Fid=1176180>
- Gebele, D., & Kaleta, M. (2019). Lehrer_innenprofessionalisierung für sprachliche Förderung mit digitalen Medien in heterogenen Lerngruppen. *Herausforderung Lehrer*innenbildung - Zeitschrift zur Konzeption, Gestaltung und Diskussion*, 2(3), 123–145. <https://doi.org/10.4119/hlz-2477> (123-145 Seiten / Herausforderung Lehrer*innenbildung - Zeitschrift zur Konzeption, Gestaltung und Diskussion, Bd. 2 Nr. 3 (2019): Lehrerinnen- und Lehrerbildung für die inklusive Schule - Fachdidaktische und bildungswissenschaftliche Ansätze).
- Ghysels, J., & Haelermans, C. (2018). New evidence on the effect of computerized individualized practice and instruction on language skills. *Journal of Computer Assisted Learning*, 34(4), 440–449. <https://doi.org/10.1111/jcal.12248>
- Juhani Lyytinen, H., Semrud-Clikeman, M., Li, H., Pugh, K., & Richardson, U. (2021). Supporting Acquisition of Spelling Skills in Different Orthographies Using an Empirically Validated Digital Learning Environment. *Frontiers in Psychology*, 12, 566220. <https://doi.org/10.3389/fpsyg.2021.566220>
- Jung, S., Huber, S., Heller, J [Juergen], Grust, T., Möller, K., & Nuerk, H.-C. (2016). Die Tübingen LernPlattform zum Erwerb numerischer und orthografischer Kompetenzen (TULPE). *Lernen Und Lernstörungen*, 5(1), 7–15. <https://econtent.hogrefe.com/doi/full/10.1024/2235-0977/a000112>
- Kline, S. M., & McCartney, S. J. (2018). Mediators of Inequity: Online Literate Activity in Two Eighth Grade English Language Arts Classes. *UVM ScholarWorks*, 1-25. <https://scholarworks.uvm.edu/mgreview/vol4/iss1/4/>
- Knopf, J. (2016). Schreiblern-Apps: Kriterien und Herausforderungen. In J. Knopf & U. Abraham (Eds.), *Deutsch digital: Theoretische Grundlagen und Implikationen für die Praxis/Praxisband* (30-35). Schneider Verlag Hohengehren.
- Knopf, J., & Brodt, J. (2016). Grammatik lernen mit Anton. In J. Knopf & U. Abraham (Eds.), *Deutsch digital: Theoretische Grundlagen und Implikationen für die Praxis/Praxisband* (pp. 147–153). Schneider Verlag Hohengehren.
- Köller, K. (2011). Individualisierung orthographischer Normerwerbsprozesse durch digital gestützte Rechtschreibstrategien – theoretische Grundlagen und exemplarische Konzeption einer Lernsoftware: Dissertation zur Erlangung des akademischen Grades „Doktor der Philosophie“ im Fach Germanistische Sprachwissenschaft an der Universität Paderborn. <https://core.ac.uk/download/pdf/50519717.pdf>
- Krammer, S., Vogt, K., Steinbrink, C., Mayer, J., Halici, O., Kruse, S., & Bernauer, J. (2006). Web-based diagnosis and therapy of auditory prerequisites for reading and spelling. *GMS Medizinische Informatik, Biometrie Und Epidemiologie*. <https://www.egms.de/static/en/journals/mibe/2006-2/mibe000036.shtml>
- Majid, S. N. A., & Salam, A. R. (2021). A Systematic Review of Augmented Reality Applications in Language Learning. *International Journal of Emerging Technologies in Learning (IJET)*, 16(10), 18–34. <https://doi.org/10.3991/ijet.v16i10.17273>

Finding pathways to effective learning environments: A Systematic Review of online learning for first language spelling education

Simbeck, K., Sellmeijer, N., Schatz, A., Pinkwart, N.

- Mangina, E., Chiazese, G., & Hasegawa, T. (2018). AHA: ADHD Augmented (Learning Environment). In IEEE (Ed.), IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE). IEEE. <https://doi.org/10.1109/tale.2018.8615222>
- Maskati, E., Alkeraiem, F., Khalil, N., Baik, R., Aljuhani, R., & Alsobhi, A. (2021). Using Virtual Reality (VR) in Teaching Students with Dyslexia. *International Journal of Emerging Technologies in Learning (IJET)*, 16(09), 291–305. <https://online-journals.org/index.php/i-jet/article/view/19653>
- Müller, H. G. (2008). Das Onlineportal Orthografietrainer.net - Lernpsychologische und didaktische Überlegungen zu einem automatisierten digitalen Übungskonzept. <https://orthografietrainer.net/service/Psychologisch-didaktischer%20Hintergrund%20Orthografietrainer.net.pdf>
- Müller, H. G. (2017). Zur Steigerung der Lern- und Leistungsmotivation im eLearning durch Elemente der Gamification. <https://orthografietrainer.net/service/Dokumentation%20des%20Motivationssystems%20auf%20Orthografietrainer.net.pdf>
- Neumann, D., & Stahl, C. (2017). Analyse der Lern-App Hallo Deutsch für Kinder von phase6: Stärken und Schwächen einer digitalen Lernressource. In C.-C. Fey & E. Matthes (Eds.), *Das Augsburger Analyse- und Evaluationsraster für analoge und digitale Bildungsmedien (AAER). Grundlegung und Anwendungsbeispiele aus interdisziplinärer Perspektive* (pp. 167–182). https://opus.bibliothek.uni-augsburg.de/opus4/frontdoor/deliver/index/docId/66333/file/Artikel_Stahl_9783781556089.pdf
- Paramythis, A., & Loidl-Reisinger, S. (2003). Adaptive learning environments and e-learning standards. In R. Williams (Ed.), *2nd European Conference on e-Learning: Glasgow Caledonian University, Glasgow, 6-7 November 2003*. Academics Conferences International.
- Parmaxi, A., & Demetriou, A. A. (2020). Augmented reality in language learning: A state-of-the-art review of 2014–2019. *Journal of Computer Assisted Learning*, 36(6), 861–875. <https://onlinelibrary.wiley.com/doi/full/10.1111/jcal.12486>
- Potocki, A., Chailleux, M., Gimenes, M., & Pylouster, J. (2021). Provoc : An app to train vocabulary depth in order to foster children's reading comprehension. *Journal of Computer Assisted Learning*, 37(5), 1324–1335. <https://onlinelibrary.wiley.com/doi/full/10.1111/jcal.12572>
- Pröbl, A. (2016). Evaluation des computergestützten phonologischen Trainingsprogramms Lautarium zur Förderung des Schriftspracherwerbs. https://kluedo.ub.uni-kl.xn--de/frontdoor/deliver/index/docId/4309/file/_Dissertation_Evaluation+des+computergestzttzen+phonologischen+Trainingsprogramms+Lautarium+zur+Frderung+des+Schriftspracherwerbs_online-qmr80e.pdf
- Ronimus, M., Eklund, K., Westerholm, J., Ketonen, R., & Lyytinen, H. (2020). A mobile game as a support tool for children with severe difficulties in reading and spelling. *Journal of Computer Assisted Learning*, 36(6), 1011–1025. <https://onlinelibrary.wiley.com/doi/full/10.1111/jcal.12456>
- Rösch, S., Jung, S., Huber, S., Artemenko, C., Bahn Müller, J., Heller, J [Jürgen], Grust, T., Nürk, H.-C., & Möller, K. (2016). Training arithmetic and orthography on a web-based and socially-interactive learning platform. *International Journal of Education and Information Technologies*, 10. https://www.researchgate.net/publication/309530051_Training_arithmetic_and_orthography_on_a_web-based_and_socially-interactive_learning_platform
- Rossiter, A. (2021). The Importance of Grammar. Online Submission. <https://eric.ed.gov/?id=ED613321>
- Schöfl, M. (2016). Delfino – Ein Online-Förderwerkzeug bei LRS für den Einsatz in der Klasse. *Lernen Und Lernstörungen*, 5(2), 111–118. <https://econtent.hogrefe.com/doi/abs/10.1024/2235-0977/a000132?journalCode=lls>
- Scholten-Theuerzeit, G., & Görlich, S. (2007). Usability mit Erstklässlern: Warum Gebrauchstauglichkeitsuntersuchungen besonders bei Erstlernern wichtig sind. *Bildungsforschung*, 4(1). https://www.pedocs.de/frontdoor.php?source_opus=4630
- Schröter, E., & Kochan, B. (2001). "Begleitetes Rechtschreiben" – ein für multimediales Lernen entwickeltes interaktives Verfahren zum individuellen Rechtschreiblernen. 9. Europäischer Kongress- Und Fachmesse Für Bildungs- Und

Finding pathways to effective learning environments: A Systematic Review of online learning for first language spelling education

Simbeck, K., Sellmeijer, N., Schatz, A., Pinkwart, N.

Informationstechnologie, 9, 1–6. https://www.redaktion.tu-berlin.de/fileadmin/fg139/Texte/Veroeffentlichungen_CLW/Begleitendes_Rechtschreiben.pdf

Schwaiger, A., Ebner, M [Markus], & Ebner, M [Martin] (2018). German Language Training App for Primary School Children. In T. Bastiaens (Ed.), *EdMedia + Innovate Learning: World Conference on Educational Media and Technology* (pp. 1222–1230). Association for the Advancement of Computing in Education (AACE). <https://www.learntechlib.org/p/184332/>

Simpson, T., & Park, S. (2013). The Effect of Technology-Supported, Student-Centered Instruction on Seventh Grade Students' Learning in English/Language Arts. In R. McBride & M. Searson (Eds.), *SITE 2013* (pp. 2431–2439). Association for the Advancement of Computing in Education (AACE). <https://www.learntechlib.org/p/48467/>

Statistisches Bundesamt. (2020, December 8). Digitales Lernen nimmt stark zu: Pressemitteilung Nr. N 081 vom 8. Dezember 2020 [Press release]. Wiesbaden. https://www.destatis.de/DE/Presse/Pressemitteilungen/2020/12/PD20_N081_63.html

Ströbel, M., Kerz, E., & Wiechmann, D. (2020). The Relationship Between First and Second Language Writing: Investigating the Effects of First Language Complexity on Second Language Complexity in Advanced Stages of Learning. *Language Learning*, 70(3), 732–767. <https://onlinelibrary.wiley.com/doi/full/10.1111/lang.12394>

Tan Geok Tin, Noor Azean Atan, Mohd Nihra Haruzuan Bin Mohamad Said, Mohd Fazli Ali, Sanitah Mohd, & Mohd Zolkifli Hamid (2018). Integrating Animations in Chinese Character Writing Based on Cognitive Theory of Multimedia Learning to Promote Students' Writing Skills. In IEEE (Chair), *2018 IEEE 10th International Conference on Engineering Education (ICEED)*. https://www.researchgate.net/profile/Mohd-Nihra-Haruzuan-Bin-Mohamad-Said/publication/330710578_Primary_Science_Teacher_Performance_in_Science_Process_Skills/links/5ce242ac458515712eb6a4d2/Primary-Science-Teacher-Performance-in-Science-Process-Skills.pdf

Taylor, C., Kirsch, I., Jamieson, J., & Eignor, D. (1999). Examining the Relationship Between Computer Familiarity and Performance on Computer-Based Language Tasks. *Language Learning*, 49(2), 219–274. <https://onlinelibrary.wiley.com/doi/abs/10.1111/0023-8333.00088>

Tazouti, Y., Boulaknadel, S., & Fakhri, Y. (2019). Imaleg: A Serious Game for Amazigh Language Learning. *International Journal of Emerging Technologies in Learning (IJET)*, 14(18), 28–38. <https://online-journals.org/index.php/i-jet/article/view/10854>

Titterton, J., & Bates, S. (2018). Practice makes perfect? The pedagogic value of online independent phonetic transcription practice for speech and language therapy students. *Clinical Linguistics & Phonetics*, 32(3), 249–266. <https://doi.org/10.1080/02699206.2017.1350882>

van Weerdenburg, M., Tesselhof, M., & van der Meijden, H. (2019). Touch-typing for better spelling and narrative-writing skills on the computer. *Journal of Computer Assisted Learning*, 35(1), 143–152. <https://doi.org/10.1111/jcal.12323>

Wang, L. (2019). Using Digital Making Words Lessons as a Guided Invented Spelling Instructional Strategy. In T. Bastiaens (Ed.), *EdMedia + Innovate Learning: World Conference on Educational Media and Technology* (pp. 1246–1250). Association for the Advancement of Computing in Education (AACE). <https://www.learntechlib.org/p/210133/>

Warren, S. J., Dondlinger, M. J., & Barab, S. A. (2008). A MUVE Towards PBL Writing. *Journal of Research on Technology in Education*, 41(1), 113–140. <https://doi.org/10.1080/15391523.2008.10782525>

Winkler, T., Stahl, J., Jahn, G., & Herczeg, M. (2015). Spellit 3.0 - Ein mobiles Miteinander- Lernspiel zum Erwerb der Schriftsprache. In A. Weisbecker, M. Burmester, & A. Schmidt (Eds.), *Mensch und Computer 2015 - Workshop* (pp. 543–550). De Gruyter Oldenbourg. <https://www.degruyter.com/document/doi/10.1515/9783110443905/pdf#page=559>

Zare, M., Amani, M., & Sadoughi, M. (2020). The role of Persian-language word exercise games in improving spelling of students with dyslexia: Word exercise games in improving spelling. *Journal of Computer Assisted Learning*, 36(3), 315–322. <https://onlinelibrary.wiley.com/doi/full/10.1111/jcal.12400>

Finding pathways to effective learning environments: A Systematic Review of online learning for first language spelling education

Simbeck, K., Sellmeijer, N., Schatz, A., Pinkwart, N.

Zou, B. (2006). An investigation of using the computer for reading and writing in the English classroom in secondary schools in the UK. *International Journal of Emerging Technologies in Learning (IJET)*, 1(3).
<https://www.learntechlib.org/p/45304/>