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Facilitating learning for students with special needs: a review of technology-supported special education studies

Shu-Chen Cheng[1] · Chiu-Lin Lai[2]

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Abstract Owing to physical or mental disabilities, disabled students often come across more difficulties in learning. In an effort to improve their learning, researchers have adopted technology-supported tools to enhance disabled students' adaptability to the learning environment and their learning achievement. The application of technology-supported special education has gradually increased in recent years. However, there is still a lack of investigation and analysis of the application and development trends of integrating technologies into special education. The aim of the present study was therefore to review technology-supported special education research articles by taking multiple dimensions into account, such as learning devices, learning strategies, learning domains and research issues, research subjects, types and level of disabilities, and learning environments. Based on the results, the number of studies has increased year by year, and the choice of learning devices and applications has become increasingly diverse; yet, the learning strategies still tend to be conservative since the majority of studies adopted the guided learning strategy. In addition, the application of technology has expanded to every learning domain, but is mainly focused on elementary school students and resource classrooms. Most importantly, the implementation of technology-supported special education tends not to result in teaching difficulties due to disabled students having different types and levels of disabilities. Further discussion and suggestions based on the findings can serve as a reference for teachers and researchers in special education.

✉ Chiu-Lin Lai
jolen761002@gmail.com

Shu-Chen Cheng
shuchen0306@gmail.com

[1] Graduate Institute of Applied Science and Technology, National Taiwan University of Science and Technology, Taipei, Taiwan

[2] Department of Education, National Taipei University of Education, Taipei, Taiwan

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Introduction

Special education is an adaptive form of education based on different needs according to ability and is adopted for disabled students with different features of disabilities when they cannot adjust to the regular educational system (Florian 2008). Disabled students have educational needs which differ from those of other students, with both physical and mental disabilities causing difficulty in learning (Lamsa et al. 2018). In an effort to help disabled students reduce the limitations brought by their disabilities, several researchers have specified that the support from technologies can enhance their learning engagement and their capabilities to accomplish learning tasks (Zhang 2000). Therefore, in the technology-integrated context of special education, teachers are encouraged to adjust their teaching approaches and employ computer-assisted tools to assist disabled students in their learning (Russak 2016).

In the learning contexts of technology-assisted special education, there have been a number of relevant empirical studies in different learning domains (e.g., Chang and Hwang 2018; Tu and Hwang 2018). Numerous researchers have found that the integration of computer-assisted tools and software applications can support disabled students at different learning levels with the aim of enhancing their learning achievements (Barton et al. 2017; Cumming and Draper Rodríguez 2017; Shih et al. 2014). With the advancements of mobile and ubiquitous computing technologies (Hwang et al. 2017), researchers have pointed out the opportunities provided by these technologies to support disabled students in solving their special learning needs (Stephenson and Limbrick 2015). For instance, through robot-supported learning, students with mild mental retardation could improve their learning motivation and engagement during learning activities (Özdemir and Karaman 2017). In addition, the integration of tablet computers and the software Language Builder could enhance the language skills of students with language impairment (Rodríguez and Cumming 2017). In sum, the integration of computer-assisted tools and software applications can enhance disabled students' basic life skills and provide them with knowledge and learning experiences in different learning domains (Cumming et al. 2014; Drigas et al. 2014).

On the other hand, researchers have indicated the importance of understanding the research trends and clarifying the challenges and the need for education (Hwang and Wu 2014), especially for special education (Karanfiller et al. 2017). Identifying the appropriateness and effectiveness of adopting computer systems and applications for different types of disabilities at different school ages can provide valuable information to identify the need for different types of special education, which can in turn help to improve the teaching quality and the students' learning performance (Ok et al. 2016). Lin and Hwang (2018) further indicated that not only the types of technology, but also the learning strategies, research issues, and learning environments are important dimensions for analyzing the trends of technology-based learning in specific applications. Therefore, it is important to examine learners' needs from multiple dimensions based on the experiments and findings of previous studies using technologies in special education (Fernández-López et al. 2013).

Compared to the trend analysis studies of technology-enhanced learning, few studies have been conducted to review the research related to the use of technologies in special education. Cumming and Draper Rodríguez (2017) reviewed and analyzed 28 studies relevant to technology-supported special education in 2007–2016. However, their review mainly focused on the use of mobile technologies rather than providing a whole view of the impact of using those technologies with different strategies and educational objectives on learners' performance and perceptions in special education. Therefore, in addition to the coding items used by Cumming and Draper Rodríguez (2017), the present study examines the current situation and development trends of applying computer-assisted tools and software applications in special education from various aspects, including learners' age, the type of technologies, the type of disabilities, the learning environments, and the application domains. This study also added some new codes to extend our view of computer-assisted special education, such as learning strategies, research issues, and levels of disabilities, which were not taken into account in previous review studies. In addition, based on the suggestion of several previous review studies (e.g., Chang et al. 2018; Lin et al. 2014), this study analyzed authors' nationalities and the development of special education in different countries or areas, which can help researchers and decision makers reexamine their policies or educational orientations. Accordingly, the following research questions were proposed:

(1) What computer-assisted tools and types of software were applied in special education from 2008 to 2017?
(2) What were the learning strategies of technology-supported special education from 2008 to 2017?
(3) What were the learning domains and research issues of technology-supported special education from 2008 to 2017?
(4) What were the research subjects, types of disabilities and levels of disabilities of technology-supported special education from 2008 to 2017?
(5) What were the learning environments of technology-supported special education from 2008 to 2017?
(6) Which countries applied technologies to special education from 2008 to 2017?

Literature review

Researchers have indicated that in technology-assisted teaching contexts, technologies, and various kinds of software applications have experienced rapid development in the past decade. However, when employing computer-assisted tools in special education, the learning contexts require a great deal of support from schools and teachers (Abidoğlu et al. 2017). Alzrayer and Banda (2017) further indicated that proper use of computer-assisted tools in special education could promote disabled students' engagement in learning activities and then enhance their confidence in learning. Nonetheless, in practice, there are difficulties in implementing technology-supported special education. For example, the study of Woodfine et al. (2008) found that students with dyslexia required a longer time to improve their reading, writing, and memory training and were less likely to have good learning outcomes in a conventional online learning environment. Another example is the study conducted by Campigotto et al. (2013), who engaged special education students in a learning task in a school library. The students were asked to take photographs using an application on an iPhone to link the photographs with the relevant vocabulary; however, most of the students encountered difficulties when using the application. That is to say, the design and application of software should take users' features and needs into consideration. This also means that special education teachers are facing new teaching challenges (Campigotto et al. 2013; Drigas et al. 2014).

Technology-based learning activities allow students to experience individualized learning, free from the constant need for teachers' involvement (Thomas et al. 2019). Its use fulfills the goal of personalized learning (Fernández-López et al. 2013), adaptive learning (Polat et al. 2012), and distance learning (Vernon-Dotson et al. 2014). However, it is notable that constant examination and evaluation are required to design a teaching software application to assist disabled students in acquiring knowledge during the learning process. Observation of disabled students' use of the software is also necessary to evaluate its applicability during the learning process (Karanfiller et al. 2017; Ok and Kim 2017). Soykan and Özdamlı (2017) indicated that in developing an instructional application for special education, it is important to conduct a pilot study in the initial design stage and invite relevant teachers and students to provide suggestions. Karanfiller et al. (2017) further pointed out the necessity of conducting large-scale tests to ensure the quality and usability of special education applications.

Researchers have specified that when integrating computer-assisted tools into teaching contexts in special education, the usage of learning strategies should be included in an effort to help disabled students successfully acquire relevant knowledge in different learning domains, especially for different school ages and different types of disabilities (Starcic and Bagon 2014). For example, Avcioglu (2013) reported that video sharing, a strategy to engage learners in playing the role of certain characters and interacting with people during the process of making videos, could be an effective method for guiding elementary school students with mental retardation to learn social skills. Evmenova et al. (2016) reported that for students with learning disabilities, mood and behavioral disorders, hyperactivity, and autism, the use of a computer-based graphic organizer with the self-regulation strategy could improve their writing outcomes. Special education teachers require more different strategies to teach. As indicated by several researchers, the more appropriate strategies the teacher selects, the more benefits the students gain (Hess et al. 2008). For example, researchers integrated the computer-based graphic organizer (CBGO) with the self-regulated learning strategy to support a writing course using a portable computer, and the results showed that it could improve disabled students' writing quality (Regan et al. 2017). Moreover, adopting game-based learning, researchers have made use of Wii (Nintendo Wii) and its functions to help disabled students with attention deficit hyperactivity disorder. The inductive receiver of the remote controller can transform into a detector of body language, and the automated reminder of vibration feedback can be used to reduce the influences of the disorder (Shih et al. 2014).

To sum up, in special education teaching contexts, computer-assisted tools have gradually become the most essential teaching tools for special education teachers and serve as one type of effective learning tool for disabled students. Most important of all, other educational software applications should serve as supplements to enhance disabled students' skill performance of using computer-assisted tools and software applications (Ok et al. 2016). The existing review studies of technology-enhanced special education mainly focus on particular issues rather than providing a whole perspective. For instance, Albarran and Sandbank (2019) discussed the effectiveness of instructive feedback for children with disabilities; Sara and Heartley (2019) investigated how computer-assisted instruction was conducted in special education; and Cinquin et al. (2019) investigated online learning environments for learners with cognitive disabilities. All of these studies provide evidence of the effectiveness of technology in special education. However, based on relevant studies on technology-supported special education, few studies have been conducted to investigate research trends of integrating computer-assisted tools and software applications into special education, in particular, by taking the multiple dimensions of the technology-based learning model, such as learning strategies and research issues, into account (Fernández-López et al. 2013). In order to provide more detailed research analysis, through a literature review, the current study examined the application of computer-assisted tools and software in the special education teaching context. Besides, based on its approach and results, the usage trends and suggestions for the future are proposed.

Research methods

Process of data searching and collection

The present study analyzed the empirical studies, explored the development and trends of integrating technologies into special education, and built up the coding scheme from different aspects, including computer-assisted tools, types of software, learning strategies, learning domains, research issues, research subjects, types of disabilities, levels of disabilities, locations, and nationalities.

The current study referred to the proposed research suggestions of Fu and Hwang (2018); they indicated that before conducting a literature review on relevant studies, renowned journal articles should be focused on and analyzed. For the present study, we searched for publications related to technology-supported special education published from 2008 to 2017 in the Web of Science (WOS) database, as shown in Fig. 1. The WOS database was adopted based on the suggestions of previous studies (Akçayır and Akçayır 2017; Fu and Hwang 2018); this database includes world-class research literature linked to rigorously selected core journals. In addition, according to the suggestions of Fu et al. (2019) and Hooshyar et al. (2019), a decade review is sufficient to predict the research trend of a specific research field. Based on

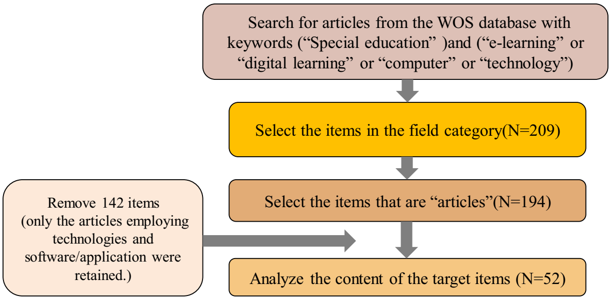


Fig. 1 WOS database searching steps

the search list of SSCI and SCI journals, there were 209 articles which met the criteria ("special education") and ("e-learning" or "digital learning" or "computer" or "technology") suggested by Hwang, Tsai, and Yang (2008). Among these 209 publications, 194 journal articles were selected. To ensure that the articles were consistent with our research purposes, two researchers with more than 5 years' experience of conducting technology-based learning studies were asked to filter the papers. By excluding those studies that did not adopt any technologies in the learning activities (e.g., integrating technology for training special education teachers, review studies, and survey studies), a total of 52 papers were included in the final list for analysis.

Data distribution

Figure 2 illustrates the distribution of computer-assisted tools and applications used in special education from 2008 to 2017. The results showed that the number of studies applying technologies in special education grew steadily throughout the 10 years, especially in the years from 2013 to 2017. This result is consistent with Ok and Kim's (2017) research in which a total of 20 journal articles published from 2011 to 2015 relevant to iPad- and iPod-supported learning for disabled students could be found. Each of these studies described how to employ iPads or iPods and associated software in teaching.

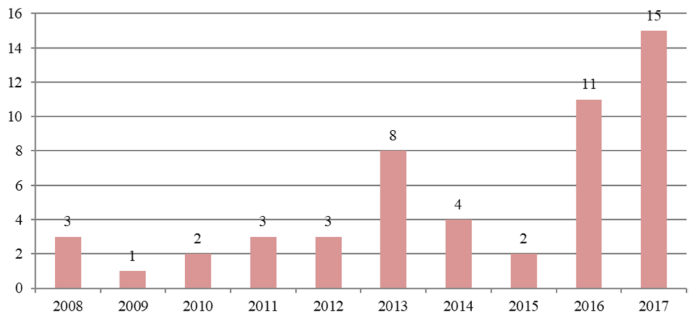


Fig. 2 Distribution of technology-supported special education from 2008 to 2017

As can be seen, the adoption of computer-assisted tools and applications in special education underwent a revolutionary change. It could be inferred that there was little research relevant to applying technologies in special education before 2012.

Coding scheme and process

A coding scheme was constructed to cover different aspects, including computer-assisted tools, types of software, learning strategies, learning domains, research issues, research subjects, types of disabilities, levels of disabilities, learning environment, and authors' nationalities. The two researchers manually read and categorized the papers based on the coding scheme. They were asked to discuss any inconsistent coding values until they reached agreement on them. Detailed descriptions are provided as follows:

Computer-assisted tools and types of software

The coding scheme of computer-assisted tools in the present study referred to the investigation of mobile devices from Chang et al. (2018) and the coding scheme from Stephenson and Limbrick (2015), including PDAs (personal digital assistants), smart phones, tablet computers, notebooks, personal computers, multimedia players, mixed and varied, and not specified. In addition, the study synthesized the research questions and constructed the coding scheme for sources of software or applications, including researcher-developed learning platforms, open sources, complementary software with machines, and commercial software. Moreover, this study also constructed the coding scheme for types of software or applications, including digital videos, digital graphic applications, digital photographs, virtual reality, Web open resources, mobile applications, document processing software, game-based applications, mixed, not specified, and others.

Learning strategies

The investigation of mobile learning by Tu and Hwang (2018) served as the reference for the coding scheme of learning strategies in the current study. Also, the research questions of the present study were synthesized to construct the coding scheme for learning strategies, including guided learning, peer assessment, video sharing, synchronous sharing, issue-based discussion, computers as Mindtools, project-based learning, inquiry-based learning, contextual mobile learning, game-based learning, and self-regulated learning. Guided learning indicates the studies that directly provided e-learning content for students, whereby the students used any kind of device to access the material by themselves. Peer assessment indicates the learning process that guided students to evaluate other works based on criteria provided by the teacher. Video sharing indicates those learning activities for which the students needed to record their own videos and share their learning performance with others. Synchronous sharing indicates that the students used a learning platform that allowed them to collaborate with others synchronously and complete their work together. Issue-based discussion refers to those learning activities in which students discussed and shared their experiences related to certain issues. Computer as Mindtools refers to some learning tools that allow students to organize their learning knowledge, such as concept maps. Project-based learning indicates some activities in which the learners need to explore a problem, find a solution, try to solve the problem, and then arrange their findings into a report. Inquiry-based learning means the activities that encourage students to observe and identify problems or solutions. Contextual mobile learning indicates those activities that guide students to learn in the real-world context and further help students to connect the knowledge from the textbook to the real world. Game-based learning indicates the activities that help students to learn about certain subjects or skills as they play. Finally, self-regulated learning indicates those learning activities that train students to engage in autonomous learning.

Learning domains and research issues

The coding scheme for learning domains refers to the coding scheme of learning domains from Fu and Hwang (2018) and the mobile coding from Cumming and Draper Rodríguez (2017), including languages, writing, reading, mathematics, science, academic skills, social skills, vocational education, communication training, action training, and assistive technology use. Assistive technology refers to equipment or a system that enhances disabled students' learning, working, or daily living. In addition, the coding scheme for research issues proposed by Fu and Hwang (2018) served as the reference for the present study, including the technology acceptance model or intention of use, attitudes, motivation and anticipation of effort, self-efficacy, confidence and anticipation performance, satisfaction or interest, cognitive load, learning anxiety, learning achievements (cognitive), learning achievements (skillful), learning behavior or engagement (including learning path), opinion of learner or learning perception (including interview or open-ended questions), correlation or cause-and-effect analysis (including model value, social influence, or influence factor), higher-order skills (including problem solving, meta-cognitive, critical thinking, or creativity), and collaboration or communication. Learning behavior or engagement refers to the research issues analyzing learners' behaviors observed by the researchers or their learning logs recorded by some learning platform to predict the students' learning performance.

Research subjects, types of disabilities, levels of disabilities

The coding scheme for research subjects referred to Tu and Hwang (2018), including elementary school, junior high school, senior high school, higher education, adults, and mixed. Also, the coding scheme for types of disabilities referred to Liu et al. (2013), including mental retardation, visual impairment, hearing loss, language impairment, emotional behavioral disorders, learning disability, physical disabilities, autism spectrum disorder, cerebral palsy, and mixed disabilities. In terms of the coding scheme for levels of disabilities, the present study referred to Blumberg et al. (2013), with options including mild, moderate, severe, and mixed.

Learning environments

Based on the coding scheme for learning environments in previous special education studies, the learning environments in special education were generally categorized into general classroom, resource classroom, school, home, and non-limited (Odom et al. 2015; Webber et al. 1993). A general classroom is a classroom for teachers to give instruction. A resource classroom refers to the learning spaces where a special education teacher or paraprofessional instructs and assists disabled students. School campus refers to the learning places on the school campus where students engage in activities, not including classrooms.

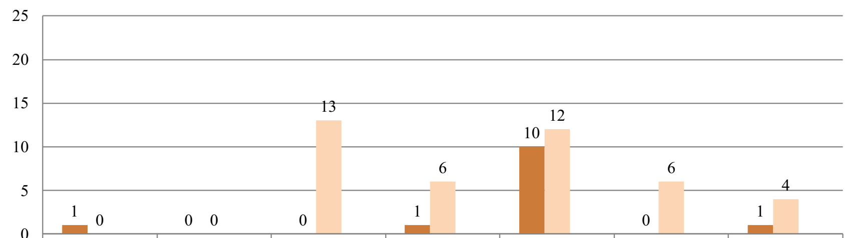
Authors' nationalities

Further analysis was conducted to explore which countries made frequent contributions to the literature on integrating mobile technologies into special education. In this study, the nationality of the article is determined according to the nationality of the first author based on the suggestion of Lin and Hwang (2018).

Research results

Computer-assisted tools and applications

The present study analyzed the studies on integrating computer-assisted tools into special education published from 2008 to 2017, as shown in Fig. 3. To further analyze the trend of technology-supported special education, the studies are categorized into two time durations, that is, the first 5 years (2008–2012) and the last 5 years (2013–2017). In the period of 2008 to 2012, learning activities which applied computer-assisted tools in special education did not gain in popularity. Only personal computers received more recognition, while the utilization rates of other mobile devices such as PDAs, notebooks, and mixed and varied were extremely low. In contrast, during the period from 2013 to 2017, there was a large-scale growth trend of

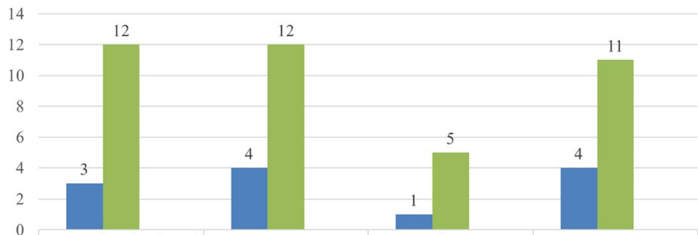


	Personal digital assistants	Smartphones	Tablet computers	Notebooks	Personal computers	Multimedia players	mixed/varied
2008-2012	1	0	0	1	10	0	1
2013-2017	0	0	13	6	12	6	4
2008-2017	1	0	13	7	22	6	5

Fig. 3 Computer-assisted devices used in special education from 2008 to 2017

employing computer-assisted tools in learning activities in special education. In particular, through the Internet, the extensive usage of tablet computers allowed learners to conduct learning activities anytime and anywhere (Cumming and Draper Rodríguez 2017). Additionally, the utilization rate of personal computers showed slow growth; yet, it was notable that notebook usage increased significantly, while the rate of using multimedia players rose gradually. On the other hand, the results indicated that smart phones were not adopted in special education because computer-assisted tools used by disabled students were provided by the schools. Nonetheless, smart phones are one kind of personal communication device which is usually used as an individual auxiliary tool for learning in daily life (Beal-Alvarez and Huston 2014). Lastly, the results suggest that future studies can keep focusing on the utilization rate, application, and development trends of applying mixed and varied wearable mobile devices in special education.

The findings of sources of software or applications adopted in the studies are shown in Fig. 4. In the period of 2008 to 2012, it was not common to employ software or applications in learning activities in special education. During these 5 years, open source and commercial software were mainly and extensively adopted in learning activities in special education, followed by researcher-developed learning platforms. However, in the period of 2013 to 2017, there was breakthrough growth in applying software or applications to conduct learning activities; particularly, researcher-developed learning platforms and open source software were extensively employed. This indicates that not all types of software are suitable for disabled students' learning. In light of this, taking the specific needs of special education into consideration, other teachers and researchers continuously developed learning software for disabled students based on the distinctiveness and different levels of their disabilities. For instance, Kurzweil was developed for supporting reading difficulties, Dragon Naturally Speaking was designed for supporting writing, and serious games as job training were adopted to improve the learning achievement and skills performance of disabled students (White and Robertson 2015; Kwon and Lee 2016). In sum, it was found that most of the studies tended to use tablet computers or personal computers with researcher-developed learning platforms, open source software, or commercial software in the learning activities for disabled students.



	Researcher-developed learning platform	Open sources	Complementary software with machine	Commercial software
2008-2012	3	4	1	4
2013-2017	12	12	5	11
2008-2017	15	16	6	15

Fig. 4 Sources of software or applications used in special education from 2008 to 2017

This study also further analyzed the types of software or applications used in special education, as demonstrated in Table 1. In the period of 2008 to 2012, it was not common to employ software or applications in learning activities in special education. During these 5 years, Web open resources (e.g., VHM Web site, NetLogo) and document processing software (e.g., Microsoft visual basic V6, Microsoft PowerPoint), as well as not specified, were mainly and extensively adopted in the special education learning activities. These were followed by mixed (e.g., using the computer's built-in functions) and other (e.g., robot and ARTUR—a kind of computer-based speech training aid) applications which presented slow growth. In the period of 2013 to 2017, there was increasing diversity in applying different types of software or applications to conduct learning activities in special education; particularly, Web open resources and mobile applications presented breakthrough growth. There was still continuous growth in game-based applications and document processing software applications in the learning activities, while the rate of using digital videos and digital photographs, as well as virtual reality, showed a gradually increasing trend.

Learning strategies

The study examined the learning strategies adopted when applying technologies in special education from 2008 to 2017, as illustrated in Fig. 5. In the period of 2008 to 2012, it could be found that the guided learning strategy was mainly adopted to conduct learning activities employing computer-assisted tools in special education. Then, in the period of 2013 to 2017, the usage of the guided learning strategy multiplied many times and became the mainstream strategy. This revealed that the guided learning strategy could help special education teachers receive disabled students'

Table 1 Types of software or applications used in special education from 2008 to 2017

Research issues	2008–2012	2013–2017	SUM
Digital videos	0	2	2
Digital graphic applications	0	1	1
Digital photographs	0	2	2
Digital music applications	0	0	0
Augmented reality	0	0	0
Virtual reality	0	2	2
Web open resources	4	12	16
Mobile applications	0	10	10
e-books	0	0	0
Social community applications	0	0	0
Communication software	0	0	0
Document processing software	3	4	7
Game-based application	0	5	5
Mixed	1	0	1
Not specified	3	1	4
Other	1	1	2

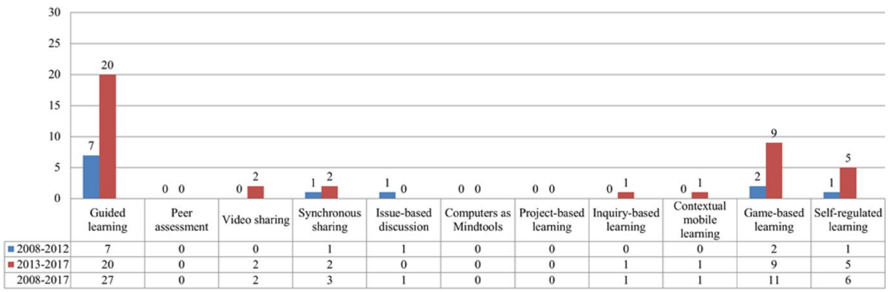


Fig. 5 Learning strategies used in special education from 2008 to 2017

feedback immediately and allowed them to observe students' learning situation to achieve effective learning. This also indicates the reason why the guided learning strategy was often adopted in the learning activities in special education (Ledford et al. 2012). On the other hand, game-based learning also received researchers' recognition and application in special education during these 5 years. It could not only replace the traditional learning style, but could also be applied in different disciplines, and the difficulty levels of games could be adjusted according to the different needs of disabled students in an effort to enhance their learning achievement (Bakker et al. 2016; Marino and Beecher 2010). Above all, based on the results, it could be found that other learning strategies have not been employed so far, for example, peer assessment, issue-based discussion, computers as Mindtools, project-based learning, and inquiry-based learning. Many studies have already pointed out the effectiveness of applying the abovementioned learning strategies in computer-assisted learning (Chang et al. 2018; Chen et al. 2016). As a result, it is recommended that special education teachers should make attempts to integrate those strategies into learning activities for disabled students in the future.

Learning domains and research issues

The study explored the learning domains of integrating computer-assisted tools and software in special education from 2008 to 2017, as depicted in Fig. 6. In the period of 2008 to 2012, it could be seen that the application of computer-assisted tools in each learning domain in special education was not extensive; in terms of mathematics, computer-assisted tools were adopted most often to assist disabled students in learning, followed by assistive technology. In the period of 2013 to 2017, in general, applying computer-assisted tools in each learning domain gradually became more popular, while social skills courses employed them the most to improve disabled students' learning. Apart from that, the utilization rate in reading and mathematics increased. In other words, this indicated that considering the special needs of disabled students, continuously regulating and improving the usage of computer-assisted tools and software applications provided special education teachers with flexible teaching tools in different learning domains (Barton et al. 2017; Ok et al. 2016).

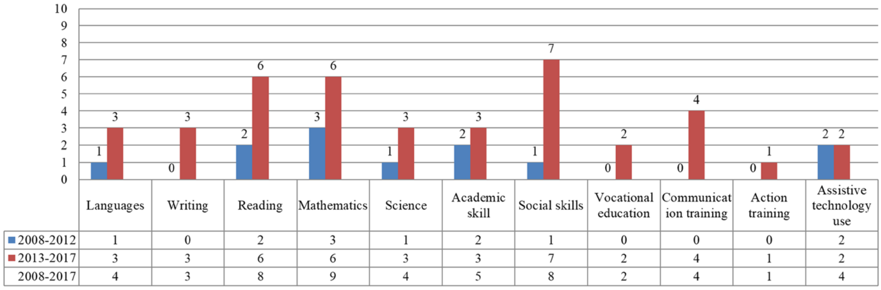


Fig. 6 Learning domains in special education from 2008 to 2017

The current study investigated empirical studies relevant to applying computer-assisted tools in special education and analyzed them based on the first research issues, as demonstrated in Table 2. In learning activities integrating computer-assisted tools in special education, the research issue of disabled students' learning achievements (cognitive) and learning achievements (skillful) accounted for the majority. In view of this, during the learning process of applying computer-assisted tools, special education teachers mainly helped disabled students gain and maintain the basic academic skills (Rakap 2010). Lastly, learning behavior was also an issue focused on by special education teachers. According to Martella and Marchand-Martella (2015), if disabled students with autism spectrum disorder want to enhance their learning achievements (both skillful and cognitive), their learning behavior must be improved first. As a consequence, it is suggested that future studies can keep emphasizing the trends of learning behavior of different types of disabled students. Apart from that, it is suggested that special education teachers can attempt to explore disabled students' satisfaction or interest, cognitive load, learning anxiety,

Table 2 Distribution of the research issues in special education from 2008 to 2017

Research issues	2008–2012	2013–2017	SUM
Technology acceptance	0	1	1
Academic attitude/motivation	0	3	3
Self-efficacy	0	2	2
Academic learning interests/satisfaction	0	0	0
Cognitive load	0	0	0
Learning anxiety	0	0	0
Learning achievement: cognitive	7	12	19
Learning achievement: skillful	2	12	14
Learning behavior	0	5	5
Learner opinion/learning experience	0	2	2
Influence relationship/causal analysis	0	0	0
Higher-order thinking	1	1	2
Collaboration and communication	2	2	4

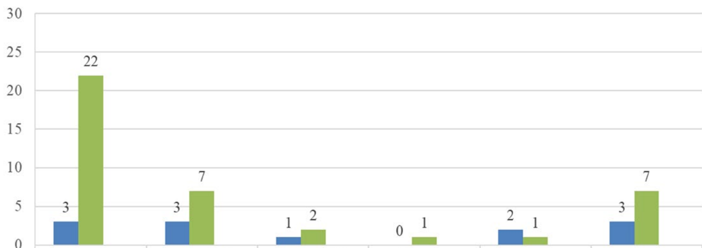
correlation, or cause-and-effect analysis (including model value, and social influence or influence factors).

Research subjects, types of disabilities, levels of disabilities

This study examined the different research subjects, types of disabilities, and levels of disabilities addressed in articles integrating computer-assisted tools in special education from 2008 to 2017, as shown in Fig. 7. Overall, the first three research subjects were elementary school students, mixed, and junior high school students. As a whole, computer-assisted tools were mainly employed in learning activities in elementary school. They could not only train students to use computer-assisted tools, but also to improve and correct their learning problems (Bakker et al. 2016). Also, this indicated that computer-assisted tools were appropriate to be employed for research subjects with mixed disabilities. That is to say, in special education environments, computer-assisted tools were often implemented for mixed disabled students in elementary schools. The results showed that technology-based learning tools could provide more convenient communication and individual learning, which was appropriate for different ages (Tsiopela and Jimoyiannis 2017).

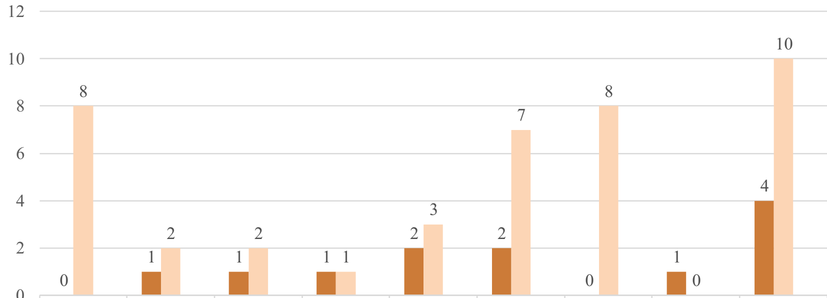
In addition, the findings of types of disabilities are illustrated in Fig. 8. In 2008–2012, few studies considered the use of technologies for specific types of disabled students. In 2013–2017, more researchers paid attention to specific types of disabilities (e.g., mental retardation, attention deficit hyperactivity disorder, learning disability, and autism spectrum disorder). However, it can be seen that disabled students who participated in learning activities were mainly mixed, followed by mental retardation, autism spectrum disorder, and learning disability. In light of this, when disabled students used computer-assisted tools, their learning would not be influenced due to the limitation of mixed disabilities, which also highlights the compatibility and flexibility of computer-assisted tools.

With regard to levels of disability, the results are shown in Fig. 9. When arranging learning activities for disabled students based on their types of disabilities, the majority of studies conducted learning activities for students with mixed disabilities,



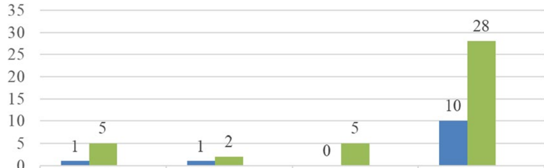
	Elementary school students	Junior high school students	Senior high school students	Higher education	Adults	Mixed
2008-2012	3	3	1	0	2	3
2013-2017	22	7	2	1	1	7
2008-2017	25	10	3	1	3	10

Fig. 7 Research subjects in special education from 2008 to 2017



	Mental retardation	Visual Impairment	Hearing loss	Language impairment	Attention deficit hyperactivity disorder	Learning disability	Autism spectrum disorder	Cerebral palsy	Mixed
2008-2012	0	1	1	1	2	2	0	1	4
2013-2017	8	2	2	1	3	7	8	0	10
2008-2017	8	3	3	2	5	9	8	1	14

Fig. 8 Types of disabilities in special education from 2008 to 2017



	Mild	Moderate	Severe	Mixed
2008-2012	1	1	0	10
2013-2017	5	2	5	28
2008-2017	6	3	5	38

Fig. 9 Levels of disabilities in special education from 2008 to 2017

followed by mild and severe. That is, computer-assisted tools would not have an impact on disabled students' learning based on their levels of disabilities.

Learning environments

Integrating technologies into learning environments in education enabled students to have more learning resources and receive new learning knowledge when they took part in mobile learning activities in class, which could also guide them to conduct in-depth problem solving (Rahimi et al. 2015). Figure 10 shows further exploration of learning environments of applying technologies in special education. The main learning environments were general classrooms and resource classrooms. According to Shih et al. (2014), disabled students would conduct learning activities in every domain using computer-assisted tools in general classrooms, indicating that teachers considered that disabled students were more familiar with the environments and devices in the classroom. It also revealed that resource classrooms were equipped with computer-assisted tools for disabled

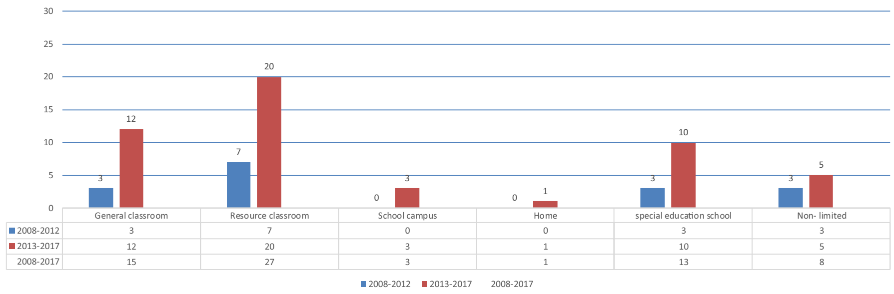


Fig. 10 Learning environments in special education from 2008 to 2017

students to learn. This is conducive to evaluating the influences of learning environments in special education schools and the learning achievement of disabled students (Kiboss 2012). Finally, learning through computer-assisted tools in non-limited learning locations, for example, blended learning or online learning out of class, could promote disabled students' engagement and learning performances (Xu 2010). With regard to professional classrooms, for example, it could assist disabled students in enhancing their job interview skills and social skills through mixed reality role-play in the virtual classroom. In the learning environment of the computer classroom, disabled students' learning achievement could be effectively increased through learning platforms (Koedinger et al. 2010; Walker et al. 2016).

Authors' nationalities

The study analyzed the nationality of the first author of journal articles integrating computer-assisted tools in special education published from 2008 to 2017, as demonstrated in Fig. 11. The first three nations were the USA, Turkey, and the Netherlands. In general, western countries have long applied computer-assisted tools to address learning problems in special education, while eastern countries are apparently lagging behind. All in all, with regard to applying computer-assisted tools in special education, the results showed the software and hardware

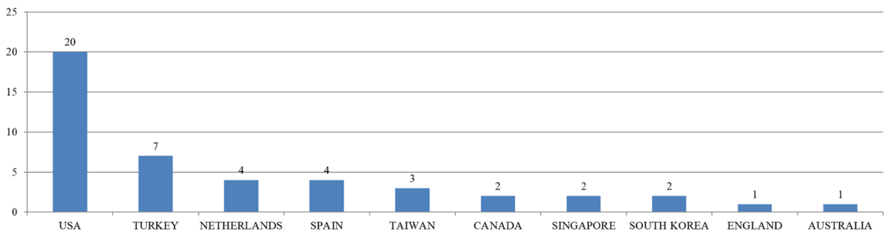


Fig. 11 Nationalities of first authors of journal articles in special education from 2008 to 2017

resources provided by the government in each country and support from schools, and special education teachers' capabilities of applying computer-assisted tools in different countries and with different cultural backgrounds (Chiang and Jacobs 2010; Okolo et al. 2011).

Discussion and conclusions

The current study is a literature review of journal articles employing computer-assisted tools in special education published from 2008 to 2017. It was found that the number of studies that employed technologies in special education has increased since 2013. The reason lies in the convenience brought by the integration of mobile devices and wireless Internet, which have resulted in a variety of mobile applications (Alzrayer and Banda 2017; Barton et al. 2017). For instance, the integration of mobile devices and learning software applications could facilitate expanded use and extension of functions to support learning activities in special education and additionally provide special education teachers with more diverse teaching approaches. Also, it assisted disabled students in using mobile devices more flexibly to promote their learning (Barton et al. 2017). Thus, when compared to other computer-assisted tools, the present study indicates that combining touch-screen tablet computers with learning software applications could offer more diverse learning methods. This could attract disabled students' interaction through the touch screen, allowing them to receive learning feedback, and improving their learning motivation (Stephenson and Limbrick 2015).

In addition, the results indicate that the application trends of computer-assisted tools changed significantly in the past decade from traditional desktop computer systems to mobile learning systems in special education. In view of this, numerous researchers in special education have indicated that the educational software applications on the market are generally not appropriate for the learning environments in special education (Hu and Han 2019; Thomas et al. 2019). Therefore, in an effort to cater to their distinctive needs and to offer more diverse choices for disabled students, many researcher-developed learning platforms have been designed. They have not only improved the applicability of the content of the learning materials for disabled students, but have also reduced disabled students' difficulties posed by applications and increased their willingness to use them (Fernández-López et al. 2013).

According to the results, it was also found that researchers tended to integrate guided learning and investigated learners' cognitive achievement, skill performance, and learning behaviors. However, few researchers have incorporated higher-level strategies (e.g., computers as Mindtools and project-based learning) into their research. As for the research subjects, types of disabilities, and levels of disability, researchers tended to investigate the effectiveness of technology for every disabled student. It is suggested that future studies can investigate the effectiveness of specific technology or learning strategies for specific disabilities, which might help teachers to find appropriate learning modes for students with specific needs.

In terms of authors' nationalities, it was found that the most productive research was published by the US researchers. This could be due to the implementation of the governmental educational programs for helping students with disabilities, such as the "Individuals with Disabilities Education Act (IDEA)" and "No Child Left Behind" (Nepo 2017; Wei et al. 2017), which encourage schools to create more inclusive classrooms and to employ technologies to cater to the learning needs of those with disabilities.

Researchers have mentioned the benefits of employing computer-assisted tools and software applications to improve students' learning achievements in special education (Abidoğlu et al. 2017; Chiang and Jacobs 2010). The greatest advantage is that software applications are developed based on theoretical foundations, enabling teachers to more effectively adopt computer-assisted tools in their teaching activities through systematic instructional design (Fitzgerald et al. 2008). In short, the integration of computer-assisted tools and software applications is an indispensable complementary tool which could support different instructional activities, promote disabled students' learning interest and learning achievement, and increase their learning efficacy.

Based on these findings, several potential research issues for technology-enhanced special education are recommended:

(1) Analyzing the interactive patterns or behavioral patterns of disabled students in technology-enhanced learning processes. The analysis results could provide valuable suggestions for developing better technology-enhanced learning tools or systems for special education, as indicated by Ke et al. (2015).
(2) Investigating the possibility of using several technology-enhanced learning strategies that are rarely adopted in special education, such as peer assessment, issue-based discussion, computerized Mindtools, project-based learning, and inquiry-based learning. On the other hand, it is also worth investigating why these strategies or tools were rarely adopted by researchers. Have they simply been ignored or are they unsuitable for special education?
(3) Investigating those seldom-discussed issues in special education, such as the impacts of technology-enhanced learning strategies or tools on students' cognitive load, learning anxiety and the correlation or cause-and-effect analysis of various factors affecting students' performances or perceptions in special education. As suggested by several previous studies, investigating these issues could be valuable for researchers to find better strategies to improve special education students' learning performances (Conti-Ramsden et al. 2010).
(4) Conducting long-term investigations on the impacts of technology-enhanced special education. Via long-term observations and data analysis, more in-depth findings could be obtained to provide valuable references for future studies or practical applications in special education, as suggested by Tsiopela and Jimoyiannis (2017).
(5) Considering the possibility of extending the learning contexts of special education from in-class activities to in-field inquiries or after-class activities with the help of technologies. As pointed out by Abidoğlu et al. (2017) and Campigotto et al. (2013), learning across contexts could help students construct knowledge and learn in a meaningful manner and hence improve their learning motivation and performances.

To sum up, the findings of the present study reveal that employing computer-assisted tools together with software applications has gradually attracted the attention of researchers of special education. However, there remain challenges and open questions about using technologies in this particular domain, as mentioned above. In addition, there are some limitations to this study. For example, the research purpose of this study was to investigate the research trend of technology use in special education; therefore, the coding scheme developed in this study cannot be generalized to all the potential issues when conducting literature reviews. It is suggested that future studies can discuss the effectiveness of different types of technology and different learning strategies for disabled students' learning. In addition, future studies can design more diverse instructional activities by adopting different computer-assisted tools and software applications to serve as a reference for researchers or school teachers in special education.

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Compliance with ethical standards

Conflict of interest Moreover, the authors would like to state that there is no potential conflict of interest in this study, and the analyzed data can be provided upon requests via sending e-mails to the corresponding author.

Ethical approval The study has been examined and advised by an academic ethics review committee. As the data were collected from an online database rather than a group of subjects, there is no privacy or personal rights problem in this study.

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Shu-Chen Cheng is a Ph.D. at the Graduate Institute of Applied Science and Technology, National Taiwan University of Science and Technology. Her research interests include mobile learning and digital game-based learning.

Chiu-Lin Lai is an Assistant Professor at the Department of Education, National Taipei University of Education, Taiwan. Her research interests include mobile learning, flipped learning, learning analytics, and digital game-based learning.