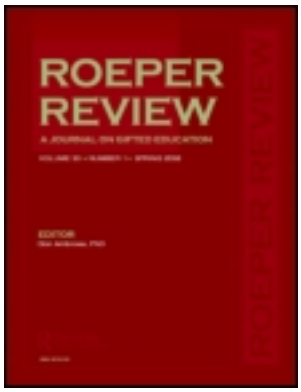

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Enable, Enhance, and Transform: How Technology Use Can Improve Gifted Education

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Enable, Enhance, and Transform: How Technology Use Can Improve Gifted Education

Jingping Chen, David Yun Dai, and Yehan Zhou

Technological use is increasingly prevalent in education. This article proposes a systematic way to conceptualize, incorporate and utilize the current technology in gifted education, namely, using "enable, enhance, and transform" as a working framework. It consists of three main functions of technological support: (a) technology *enables* gifted education to expand its capacity of service; (b) technology *enhances* the quality of gifted education; and (c) technology *transforms* gifted education by creating new directions and possibilities. The extant literature is reviewed in the hopes of understanding the current situation of technology use in light of this framework. The review shows that well-designed research is sorely needed that goes beyond mere advocacy to articulate the role of technological support and test its effectiveness in achieving specific goals of gifted education provisions.

Keywords: enable, enhance, framework, gifted education, paradigm shift, review, technology, transform

With the advent and new development of technology, many researchers and educators have started to advocate technology as one of the indispensible components of future education. Research on technology use in general educational settings has also yielded a myriad of positive results. It is also widely accepted that technology has great potential for enhancing the efficiency and quality of gifted education; some scholars even assert that certain technologies are particularly beneficial to gifted students (Pyryt, 2009; Shavinina, 2009; Siegle, 2005).

What is educational technology, and how should it be utilized in gifted education? To properly answer this question, we should first specify the scope of "technology" we are concerned with. Based on *Merriam-Webster's Online Dictionary*, the definition of technology includes three aspects: *the practical application of knowledge especially in a particular area*; *a manner of accomplishing a task especially using technical processes, methods, or knowledge*; and *the specialized aspects of a particular field of endeavor*. In other words, technology can be the tools, the usage and knowledge of the tools, as well as systems or methods of organization. However, the commonly used concept of *technology* in educational settings mostly refers to the tools and resources. For instance, in 2008, the Association for Educational Communications and Technology defined educational technology as "the study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources" (Richey, 2008, p. 24). In this article, the scope of technology is also narrowed down to the tools, programs, and resources supported by technical inventions such as computers, the Internet, and electronic devices. Knowledge of the tools or systems or methods of organization are derivative in this regard.

Some frameworks have been proposed to guide the exploration of technology use in educational settings. For example, Bruce and Levin (1997) proposed an explicit taxonomy of technology use in educational settings, arguing that educational technology should be the media for inquiry, communication, construction, and expression. In their book, called *How People Learn*, Bransford, Brown, and Cocking (2000) articulated five ways that new technologies can be used in educational settings:

- bringing exciting curricula based on real-world problems into the classroom
- providing scaffolds and tools to enhance learning
- giving students and teachers more opportunities for feedback, reflection, and revision
- building local and global communities
- expanding opportunities for teacher learning

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Mishra and Koehler's (2006) technological pedagogical content knowledge framework proposed that true technology integration is to understand and negotiate the relationships between three components of knowledge: content, pedagogy, and technology. Twining's (2002) computer practice framework tried to conceptualize computer use in education in three core interrelated dimensions, labeled *quantity* (the quantity of computer use as a proportion of the available learning time), *focus* (the objectives supported by the computer use), and *mode* (the impact of computer use on the curriculum).

Within the field of gifted education, there are also some existing frameworks for technology use. Siegle (2005) identified six different types of technology-supported learning activities for gifted and talented students: information resources, e-books, interactive projects, online classes, publishing platforms, and mentoring resources. Pyryt (2009) used the five-P model to examine how technology use enhances five key dimensions of gifted students' learning, including *pace* of learning, higher-order *process* skills development, pursuing *passion* areas, various *products* developed, and intellectual *peers* interaction. Ng and Nicholas (2007) also proposed a conceptual framework that supports gifted students' learning in online learning environments, which adopts Garrison, Anderson, and Archer's (2000) three essential layers of learning community (cognitive presence, social presence, and teaching presence) while highlighting the dialogic and concept forming processes that occur between people or between people and concepts.

All of the frameworks identified here have their own merits in guiding technology use in gifted education. However, they more or less suffer from one or more of the following problems and weaknesses. First, rather than providing a comprehensive framework about technology use, most of them only focus on one specific area of technology use, such as pedagogical practice (Bransford et al., 2000) or teacher development (Mishra & Koehler, 2006). Some focus on one specific field of technology, such as the Internet (Siegle, 2005), online learning environment (Ng & Nicholas, 2007), or computer use (Twining, 2002). Second, rather than affording a coherent, integrated view of technology use, some of them provide discrete dimensions without describing or articulating the interrelationships between the factors (Bransford et al., 2000; Pyryt, 2009; Siegle, 2005). Third, frameworks that work well for general education are not always easily translated into specific applications in gifted education, since gifted education often constitutes a unique context for technology use. Because of the lack of an overarching framework guiding research, extant studies are sporadic and have rarely examined and evaluated technology use in gifted education in a systematic manner.

More important, most of the frameworks of technology use are based on the current schooling system without considering the possibility that technology can transform education. Just as Collins and Halverson (2009) stated in their book *Rethinking Education in the Age of Technology: The Digital Revolution and the Schools*, new technologies create learning opportunities that go beyond traditional schooling; they could potentially change the way students learn in a fundamental way. A framework for technology use in gifted education should include a long-term vision beyond specific applications to make technology a deep infrastructure for a new vision of gifted education that is more accessible, flexible, and truly learner centered. Furthermore, many researchers are advocating a paradigm shift in gifted education, which views giftedness as developmental and contextual in nature rather than born and fixed (Dai & Coleman, 2005). The value of technology in enhancing or promoting this function is not well articulated in the exiting frameworks gearing toward gifted education.

What we need is a conceptual framework that both synthesizes key aspects of technology use in gifted education and provides useful guidance for research and practice. To achieve this goal, in this article we propose a framework of enable, enhance, and transform, in the hopes of helping people to incorporate and utilize the technology in gifted education by conceptualizing existing studies of technology in a systematic way.

The enable, enhance, and transform framework has three main functions, each subsuming several specific applications. First of all, technology can *enable* the expansion of gifted education by increasing its capacity and efficiency; this function is mainly that of service delivery. For example, online classes and recourses help maximize the capacity to serve more qualified and committed students who otherwise might be rejected for the lack of program slots; technology platforms might help establish services for remote areas where resources are lacking for gifted students.

Capacity augmentation provides potential for, but in and of itself does not guarantee, the quality of service. Technology can *enhance* the quality of gifted education by strengthening content presentations and pedagogical features, leading to better learning outcomes; this function is mainly for strengthening the quality of student learning rather than merely expanding capacity or improving efficiency. For example, with the help of computer-adaptive testing, the proper pacing of learning can be facilitated; with the help of computer games, online problem-solving activities can be effectively guided and monitored.

The majority of conceptions of technology use focus on capacity and quality and stop there. We propose that technology can *transform* gifted education by opening the door for all and creating new possibilities and avenues for a variety of personalized gifted expressions, talent development, and creativity to such an extent that a new way of delivering and organizing gifted education may emerge. We argue that technology has the potential not only to increase the capacity and enhance the quality of education but also to transform the mode of education. For example, technology can build widely distributed learning systems, in which

TABLE 1
A Framework for Technology Use in Gifted Education

Main Functions	*Medium and Vehicle*	*Gifted Education Components*
Enable (capacity)	Online courses and resources Virtual communities Virtual workspaces Technological platforms Publishing platforms	Increased capacity to serve Access to students in remote locations Providing abundant learning resources Building communities of learners Mentorship access
Enhance (quality)	Assessment tools Inquiry tools Pedagogical tools Production tools Presentation tools	Identification (diagnosis) Pacing of learning Inquiry-based and project-based learning Self-direction and critical thinking Impact on an audience
Transformation (mode)	Technology-supported, widely distributed learning systems Individualized, adaptive learning and managing systems Online environment for cooperation and collective innovation	Opportunities for a variety of gifted expressions, talent development, and creativity Customized learning/development goals, plans, scaffolds and processes for individuals Experiences of collective knowledge building and creation in the learning community

formal and informal learning are blurred and learning is distributed between and among schools, homes, communities, and the Internet (Barron, 2006). Networks of learners in this environment are no longer confined to classmates or school mates but self-connected through the Internet based on interests (Collins & Halverson, 2009). By immersing in the online environment for cooperation and collective innovation, the learners are also becoming positive knowledge creators instead of passive knowledge consumers (Scardamalia & Bereiter, 2006; Zhang, 2012). Taken together, the enable (capacity) and enhance (quality) functions of technology use can jointly facilitate the transformation of gifted education deemed desirable by its stakeholders.

As shown in Table 1, the three main functions of technology used in gifted education are concerned with capacity, quality, and mode, respectively. The middle column indicates media and vehicles for carrying out these functions (i.e., applications), and the right column indicates specific goals and objectives of gifted education.

In the rest of this article, we review the literature on technology use in gifted education. The enable, enhance, and transform framework are used as a lens through which to assess what has been done and what can be done with technology in gifted education. Our intent is to give practitioners an overview of the possibilities and potentialities of technology use in gifted education, as well as provide suggestions to researchers about the future direction for exploring more in-depth research topics about technology use in gifted education.

ENABLE, ENHANCE, AND TRANSFORM: A LITERATURE REVIEW

Enable: Making Things Happen

The development of technology, especially the development of the Internet, has brought many new possibilities to gifted education. In other words, technologies are greatly increasing the capacity of delivering gifted education services in many ways. For example, technologies have been used as a curriculum delivery vehicle, a tool for administering and managing online gifted education programs, and a platform for building online learning communities.

Technologies as a Curriculum Delivery Vehicle

As Baldus, Assouline, Croft, and Colangelo (2009) stated, technologies that are making gifted programs and services available to a larger number of gifted students especially open a doorway to excellence for gifted students in rural areas who cannot access more educational resources due to geographic reasons. For example, McKinnon and Patrick Nolan (1999) reported their practice of providing advanced courses in literature, cosmology, and philosophy cosmetics offered to the gifted high-school students in New South Wales, Australia. Especially designed websites, e-mail, and listservs were used to distribute and receive materials, discuss problems, and share ideas, for the purpose of serving the needs of these students whose access to universities during their high-school years was prevented by the vast distances of the Australian country. Belcastro (2005) listed some electronic technologies, including audio and videotapes, instructional television, e-mail, the Internet, and CD-ROMs, that are used to overcome the restrictive factors or barriers to delivering gifted education programs to gifted students who are blind or visually impaired in rural schools.

Some practitioners and researchers use technology to deliver online Advanced Placement (AP) courses. At the Center for Talented Youth program in John Hopkins University, certain technologies (such as interactive video, web-based discussion forums, online video, webcasting, voicemail, asynchronous discussion forums, scheduled virtual meetings, interactive white board, etc.) are used to deliver online AP courses (Wallace, 2005). The Iowa Online Advanced Placement Academy offers online AP courses and exams while combining teacher training and school development as enrichment programs for students in rural high schools in Iowa (Baldus et al., 2009). Similar practices can also be found at Stanford University (Ravaglia,

Suppes, Stillinger, & Alper, 1995) and Ball State University (Adams & Cross, 1999).

The practices outlined here indicated that talented and gifted learners, particularly those who have difficulty accessing related educational services due to lack of local resources, can benefit from various online services. Technologies help gifted students to gain access to meaningful challenges over the barrier of geographical restriction. This way, technology in effect improves gifted education in terms of achieving equity.

Technologies as Tools for Administering and Managing Online Gifted Education Programs

Among the considerable number of gifted programs nationwide, some of them employ technologies to assist the process of programming and administration, including recruiting gifted children, managing the programs, and building communities. Programs that take full advantage of this feature include the Renzulli Learning System (RLS), the Center for Talented Youth program of John Hopkins University, the Educational Program for Gifted Youth at Stanford University, the Iowa Online Advanced Placement Academy, the Center for Talent Development at Northwestern University, and the Gifted Kids Network.

The capacity of gifted programming is significantly increased with the assistance of technology. Without technology, it is almost impossible for educational institutions to manage the massive amounts of students and instructors' data, organize the abundant learning materials, and conduct efficient administrative work to those nationwide or even worldwide programs with limited resources. However, relatively little is known about how exactly the technologies have been employed to improve the efficiency of gifted education programs in terms of the management and administration or how the functionalities of technology could be improved to better serve the needs for these areas.

The only program that displays the details of implementing technology in the management system is the RLS, which is seen as a distinctive model of a comprehensive and well-structured technology-based learning platform for gifted students. On this platform, every student has a computer-generated profile that includes his or her academic strengths, interests, learning styles, and preferred modes of expression. A search engine is used to match Internet resources to the student's profile from 14 carefully screened data bases that are categorized by subject area, grade level, state curricular standards, and degree of complexity. A management system called the Wizard Project Maker guides students in the application of knowledge to teacher- or student-selected assignments, independent research studies, or creative projects that individuals or small groups would like to pursue. Moreover, there is a curriculum acceleration management system for high-achieving students, which is based on a well-researched and validated differentiation process called *curriculum compacting* (Renzulli & Reis, 2009).

Technologies as a Platform for Building Online Learning Communities

With the advances in Internet technology, communicating, interacting, and cooperating with distant peers is no longer a problem. For gifted students, this could mean a new way to reach intellectual peers that is not available in their own communities, thus reducing their feelings of social isolation (Ng & Nicholas, 2007; Pyryt, 2009) and putting themselves in their own zone of proximal development (Vygotsky, 1978). Online community can also be a vehicle for collaborative knowledge construction (Scardamalia & Bereiter, 2006), as well as for access to the mentors who are experts in certain disciplines or academic fields. All of these make the notion of *online community* viable. For instance, Dove and Zitkovich (2003) described their practice of creating a learning environment that stimulates interactive inquiry and communication among the elementary gifted students on their science learning via mobile digital communication tools. Wallace (2005) also elaborated on two ways of online communication: synchronous interaction (group interactive video, desktop interactive video, live chat sessions, audio conferencing, collaborative group ware, and Internet whiteboards) and asynchronous interaction (online discussion forum, e-mail, voicemail, video mail, webcasting, collaborative document editing).

Enhance: Making Things Better

Current technology has been used in many ways to strengthen the quality of teaching methods and learning experiences, including providing tools for better assessment, more authentic inquiry, more efficient pedagogy, better production tools, and more powerful presentation tools. Various aspects of enhancing teaching and learning through technology use have been explored in research, including curriculum enrichment, assessment enhancement, and facilitation of teachers' professional development.

Technology as a Tool for Curriculum Enrichment

A variety of ways to use technology in curriculum enrichment are found in the literature. In order to organize our review, we adopted Renzulli and Reis's (2009) curriculum enrichment triad model as taxonomy. Each of the types of activities in the model carries distinct pedagogical features in motivating and engaging student learning and thinking.

Type I: General exploratory activities. According to Renzulli and Reis (2009), type I enrichment is designed to expose students to a wide variety of disciplines, topics, occupations, hobbies, persons, places, and events that would not ordinarily be covered in the regular curriculum. Some

technologies make a variety of content more accessible to the learners and help them to extend their knowledge in a cost-efficient way. For example, Wassermann (2001) described the development process and outcome of a CD-ROM in 10 secondary schools throughout British Columbia, Canada. The CD-ROM, which consists of various archival documents, video clips of interviews, as well as photos and prints, is used as a learning tool for the students to learn the history of Japanese Canadians and Japanese Americans. Wu and Ma (2009) showed that the Webquest can be an inquiry-oriented activity in which some or all of the information that students interact with comes from the Internet. Mulrine (2007) discussed the use of virtual learning environments in gifted education. He also advocated that virtual learning environments can be used to develop cultural experiences in the visual, creative, and performing arts; visit all types of museums, industries, governmental agencies, and institutions; expose students to different ideas through prominent and/or controversial persons; and provide advanced study in the content areas that include research activities. Schroth, Helfter, and Dammers (2009) proposed that the use of web-based composition tools can help students who are gifted as musicians in general or as composers to discover their potential. Gadanidis, Hughes, and Cordy (2011) also reported a study of a program for Grade 7–8 gifted students that investigated mathematic tasks with the arts and technology. The gifted students used drawing and interactive technology tools to investigate, extend, and communicate mathematical ideas. They also made use of Google and Wikipedia to research mathematical concepts. The authors believed that the use of these technology tools allows the students to control their own investigation as well as foster a collaborative knowledge building environment. In short, the wealth of resources available today not only ensures access for educational purposes but also has pedagogical features that motivate gifted children to engage and sustain a variety of enrichment and self-exploratory (informal learning) activities and thus increase the possibility for these children to explore more in a specific domain.

Type II: Group training activities. Renzulli and Reis (2009) categorized type II enrichment as consisting of materials and activities designed to develop a broad range of higher-level thinking processes and advanced inquiry skills. The development of these type II skills, especially creative thinking, problem solving, and critical thinking, is the focus of some researchers who investigate technology use in gifted education.

For example, Pyryt (2009) surveyed a variety of websites for nurturing learners' creativity and critical thinking skills.[1] Subhi (1999b) also used a controlled experiment to test the hypothesis that problem solving via the LOGO programming environment can improve primary-school gifted children's mathematics achievement and creativity (divergent thinking). Another controlled experiment was the study done by Dixon, Cassady, Cross, and Williams (2005), which compares the quality of two groups of gifted students' writing in terms of critical thinking under different writing conditions (one in handwritten form and the other using computers to compose essays). The result indicated that, compared to their female counterparts, male adolescent students benefited more from the technology use (using computers to compose the essays), in terms of the quality of thinking, number of words, sentences, and paragraphs generated.

Other advanced inquiry skills are also discussed, such as skills in the appropriate use of advanced-level research methods and reference materials, as well as written, oral, and visual communication skills. For instance, Eiselen and Fox (1990) designed a project to help elementary-school gifted students to use online bibliographic database searches in their research process. The outcomes of this project seemed to support their argument that the database search "allowed youngsters to create their own inquiry" as well as "individualize their learning" in an authentic knowledge building setting (p. 45). Siegle (2005) also delineated how technology literacy, defined as the knowledge and skills accumulated through technology application, could impact the gifted learners' inquiry skills, including integration and complexity, quick processing, critical thinking, and creative productivity.

Type III: Individual and small-group investigations of real problems. As part of Renzulli and Reis's (2009) enrichment model, type III enrichment emphasizes the students' role as first-handed inquirers who select topics based on their own interest and acquire the advanced knowledge or skills by developing authentic products for specific audiences within particular disciplines. A number of studies pertain to this topic.

For instance, Bergen (2001) recorded the practice of a teacher in a primary school, who tried to engage gifted children in developing multimedia projects using presentation software (PowerPoint) as a way of curriculum differentiation. Siegle (2009) examined producing and sharing videos as a way to encourage students to produce a high level of sophistication in their products, which might help the students "function as professionals" through advanced process (p. 16). Siegle (2005) also explored technology's potential for providing platforms for gifted learners to present their products to audiences in many ways.[2] Olszewski-Kubilius (2005) examined whether a technology platform can facilitate the instructors and students in managing advanced learning such as independent study. Eckstein (2009a) also illustrated that Web 2.0 tools, such as wikis, social bookmarking, aggregators, podcasts, collaborative documents, and blogs, including the service and software, which allow anyone to publish, share content, and collaborate with others, can be used for curriculum enrichment clusters. By using these tools, students can investigate their topics in a collaborative and constructive way, as well as present their products or services to a real audience.

Technology Brings Better Ways of Assessment

The strength of technology makes it possible for assessment in gifted education to be more individualized and formative based, thus providing better student agency in the assessment as well as better guidance for next step teaching and learning. One good example of a technology aid assessment method is computerized adaptive testing (CAT), which provides testing items with difficulty levels responsive to the levels of knowledge and capabilities that the learner demonstrates (Olson, 2005). For instance, if a student answered an item incorrectly, the subsequent item will become less difficult; conversely, a correct answer will lead to a more difficult question. By adjusting the degree of difficulty to the student, CAT can provide quick, accurate, and comprehensive feedback on students' achievements, which facilitates the modification of curriculum and personalized learning goals for each student (Clark, 2005; Olson, 2005). The diagnostic testing followed by prescriptive instruction is a good example of using CAT in real gifted education settings, by which educators were able to determine students' current levels of knowledge, analyzed the data to determine their special needs, modify and implement curriculum to meet these needs, and retest and proceed to the next stage (Stanley, 2000). CAT has already been used as a more advanced standardized assessment tool for the selection and identification of mathematically gifted and talented students, because it enables gifted educators to more accurately identify gifted and talented students (Shermis, Fulkerson, & Banta, 1996).

The RLS also uses technology to provide a more formative, individualized assessment. On this online platform, students and teachers can evaluate the quality of students' products using a rubric called "The Student Product Assessment Form." On this form, students can rate each site visited, conduct a self-assessment of what they have gained from the site, and place resources in their own total talent portfolio for future use (Renzulli & Reis, 2009).

Technology Facilitates Teachers' Professional Development

Technology is also used to facilitate the professional development of teachers, as a secondary product of technology use in gifted education. According to Besnoy (2007), the use of a personal technology improvement plan will allow teachers of the gifted to identify their technology needs and create an individualized, professional development plan. This plan can also help the teachers to progress at their own pace while meeting their learning goals as teachers of the gifted. Others also mentioned that the use of CAT will help teachers to refocus their professional development plans and teaching strategies to address areas in which student achievement was lagging because they can access individualized student data (Olson, 2005).

Transformation: Making Things Different

The gifted education movement arose as a reaction to age-graded schooling, with a one-size-fits-all curriculum and pedagogy of knowledge transmission and a theory of learning as knowledge absorption (Renzulli, 1986). The tradition of gifted education in the past century is characterized by defining gifted children as a homogenous group, identifying gifted children based on general measures of IQ or overall academic achievement, and providing enrichment and acceleration opportunities presumably suited to their ways of learning and thinking and pace of progress. Though the old paradigm might still have utility in serving the educational needs of precocious and advanced students, the new developments in information technology make it possible to change the old way we conceptualize gifted children and envisage gifted education. The possibilities include changing the definition of giftedness, transferring the ways of providing service, and altering the focus of gifted education.

From a Homogeneous, Static Definition of Giftedness to a Pluralistic, Developmental Focus

With the advent of new assessment technologies, it is no longer necessary and meaningful to use arbitrary cutoffs to determine who is gifted and who is not in order to establish a student's eligibility, a practice facing increasing criticism (Hertzog, 2009). For example, CAT (Clark, 2005; Olson, 2005) makes gifted identification shift from *once gifted, always gifted* to a dynamic, open system that is sensitive to current levels of competence and educational needs. The RLS also incorporates an assessment system that is responsive to individuality and specific strengths and interests. The system fully honors the diverse and dynamic (ongoing) nature of manifested giftedness and talents rather than adhering to a static, categorical notion of who is gifted and who is not.

From Gifted Programs to Customized Services

Technology also makes it possible to make educational services more customized, and therefore more flexible and tailored to individual needs than any gifted programs. For example, in the RLS, every student can have access to the learning resources based on their interest and needs, and the guidance for the assignments and projects, as well as the group assignments, is customized due to individual differences (Renzulli & Reis, 2009). Although educators still play a guiding role, there is a significant amount of learner control and choice in the process, which is particularly desirable for advanced, self-directed learners. At any rate, the versatility of the administration afforded by information technology and richness of Internet resources and expertise can potentially change the way we envision gifted education as an institutionalized practice.

From Serving "Special Needs" to Building Connectivity of Ideas, Values, and Worldviews

Gifted education has been a pioneer for innovations in teaching and learning (Renzulli, 1977; Tomlinson & Callahan, 1992). However, it also tends to see itself as having a separate identity, apart from the rest of education, in the name of serving "special needs" of gifted students. Conceptualized this way, gifted education has been somewhat insulated from a broad educational perspective as well as advances in technology use aimed at achieving this broad vision. Shavinina (2009) suggested that gifted education should adopt high intellectual and creative educational multimedia technologies (HICEMTs) as the possible methods for future development. A practical illustration of HICEMTs is Knowledge Forum, a second-generation version of computer-supported intentional learning environments. Differing from the traditional learning method, Knowledge Forum shifts its focus from individual thinking to collectively creating commonly shared meanings and from individual cognition to distributed cognition of a learning community (see Scardamalia & Bereiter (2006) for more information about computer-supported intentional learning environments). Other HICEMTs include computer-mediated communication, virtual classrooms, simulation training, and intelligent tutoring systems, as well the combination of these approaches, which can also be used for the purpose of broadening students' intellectual horizons and building the connectivity of ideas, people, and places (Shavinina, 2009; Siegle, 2005).

GENERAL DISCUSSION

We delineated the possibilities of how technology use enables, enhances, and transforms gifted education and reviewed the related literature. There is a general consensus that technology can be a beneficial or value-adding tool for improving the efficiency and quality of gifted education, including bringing abundant resources to distance learners (Belcastro, 2005; Cyr, 2004; Eiselen & Fox, 1990; McKinnon & Patrick Nolan, 1999, 2002; Siegle, 2005; Wallace, 2005), building online learning communities for isolated gifted learners (Adams & Cross, 1999; Baldus et al., 2009; Eckstein, 2009b; Pyryt, 2009; Shavinina, 2009; Ybarra, 2005), connecting them with mentors otherwise out of their reach (Shavinina, 2009; Siegle, 2005), providing authentic opportunities for developing higher order thinking skills and creativity (Cross, 2004b; Dixon et al., 2005; Eckstein, 2009a; Subhi, 1999a), and offering multiple ways for productive work and real-life investigations (Barab et al., 2007; Renzulli & Reis, 2009; Shavinina, 2009; Siegle, 2005). Some researchers have started to think about how the technologies can be applied to gifted education and persuaded practitioners to adopt them (Bergen, 2001; Eckstein, 2009a; Siegle, 2009). There could, of course, be a "dark side" of using technology, including:

1. The lack of integrity and ethics in using computer technology could lead to computer crimes,
2. The lack of *controlled curiosity* could make gifted students overwhelmed by information,
3. Believing that all information is contained on the Internet could make gifted students refuse to search for other resources (Pyryt, 2009), and
4. The use of computer-based communications technologies (e-mail, instant messages, chat rooms, online diaries or journals) might affect gifted students' social and emotional development (Cross, 2004a).

There are obviously many more issues to be addressed in order to use technology more effectively. For one, attitudes toward technology can directly influence the effectiveness of technology use (Russel, Bebell, O'Dwyer, & O'Connor, 2003). Shaunessy (2005) argued that attitudes of teachers of the gifted toward technology use are a crucial factor. It is important for educators to have a full understanding of the effects of technology use on gifted learners' overall development. Moreover, most of the publications we reviewed focused on using technology as a tool, a vehicle, or a platform for enhancing teaching and learning. Technology competence itself as a skill, or technology literacy, has been less of a concern.

Lack of Systematic Research

An overall assessment of the research on technology use in gifted education seems to indicate that it is in its preliminary development. Although the passion for technology use is palpable in the field of gifted education, systematic efforts to investigate the effectiveness of various approaches are still rare. Very few studies have empirically examined the instructional effects of using specific technologies. When empirical data were collected, they tended to be descriptive in nature, such as the number of students who enrolled and completed their courses per year and the grades students achieved. A majority of the articles we reviewed simply reported how technologies have been used. Some important questions remain unanswered, such as the following:

- In what ways can the technologies be used effectively to enable, enhance, or transform gifted education?
- What kinds of technologies are more beneficial to gifted learners than others, and why?
- What are some important differences between using technologies and conventional instructional methods?
- What are the essential causes of these differences between using technologies and conventional instructional ways?

- How should current gifted education be prepared for the technology-enhanced education transformation in the future?

More empirical research is clearly warranted to determine how such a customized provision system compares with the traditional provisions in its effectiveness and efficiency.

In addition, there is an imbalance in publications regarding different aspects of gifted education. Most articles have discussed the use of technology in curriculum and teaching, and relatively few have discussed the utilization of technology in identification. This suggests the lack of systematic conceptualization of technology use in the domain of gifted education. In addition, most articles have focused on using technologies to serve the academic needs of the gifted. Very few have focused on using technologies in other human endeavors, including vocational, artistic, and personal–social domains (Feldhusen, 1992). Only one study looked at using web-based and software music composition tools to help musically talented students to develop their composing skills (Schroth et al., 2009).

The lack of systematic conceptualization of the nature of technology use in gifted education makes research efforts less productive and sustainable as we continue this line of inquiry. Most of the publications on the topic are still in an advocacy mode, not truly reporting research in the exact sense of the word. It is time now to move beyond advocacy to formulate well-designed research that can answer critical questions and move gifted education forward. The enable, enhance, and transform framework can help facilitate such progress.

How the Enable, Enhance, and Transform Framework Can Guide Research

For the enabling hypothesis, researchers can address the following questions: How well does a particular technology allow gifted education to reach out to more gifted students and a more diverse range of gifted learners? How effective is a particular way of delivery, and what is the cost-effectiveness of such a delivery compared to traditional methods? What kind of local infrastructure and off-line and online support are needed for its success?

Regarding the enhancement hypothesis, it is unlikely that technology-based learning will replace classroom teaching, learning, or direct social interactions. For example, the creation of RLS does not make obsolete the previous ways of organizing enrichment clusters and activities in school. Therefore, researchers can ask whether technology use provides value-added experiential and pedagogical features that enhance the quality of particular learning experiences. For example, presumably because of gifted students' higher capability of filling in gaps left by instruction (Borkowski & Peck, 1986) or more frequent use of metacognitive control (Shore, 2000), they are poised to gain more with the kind of self-directed learning required by multiuser virtual environment–based games and simulations. However, there is no research evidence supporting such a conjecture. In other situations, technology might produce new opportunities (i.e., enabling) for learning, but the quality of this offering (i.e., enhancement) is unknown. For example, e-mentoring is considered a good option for gifted students who might not be able to find a mentor in his or her local community (Siegle, 2004). How does e-mentoring compare with in-person mentoring? What are some relative strengths and weaknesses of each approach? Research is needed to provide specifics so that the enhancement hypothesis can be substantiated.

Compared to the enabling and enhancement functions, the transformation hypothesis is more complex. Technology in and of itself, of course, will not produce miracles, but it does create conditions that make more radical changes possible implied by the term *paradigm shift*. Collins and Halverson (2009) envisioned a future of education where customization, learner control, and interactivity become new norms for learning. They even boldly argued that schooling as we know it is obsolete in an age of technology where information and knowledge grow and flow at a rapid pace and where individuals gain access to them with unprecedented ease. Although rapid transformation of schooling will not happen any time soon, one thing is certain: if technology will eventually help revamp the school system (fixed curriculum for all, age-graded classes, transmission model of learning and warehouse model of knowledge, and standardization of evaluation), it will revamp gifted education as well.

Regarding the transformation function of technology, the main research task is to determine how technology use might cause systemic changes in the way gifted education operates. For example, if assessment tools, better calibrated and more sensitive to individuality (i.e., computerized adaptive testing and cognitive diagnostic assessment), eventually replace traditional standardized tests in gifted identification, and if identification of strengths and interests can be quickly matched with appropriate learning activities (as RLS does), then the nature of identification will undergo fundamental changes, from categorizing or selecting a group of children for special treatments to diagnosis of current levels of mastery or zones of proximal development for proper interventions. Moreover, the changing technology of assessment might even lead to a realization that all cutoffs we set up for gifted identification are arbitrary to some extent, out of administrative convenience rather than psychological necessity (Hertzog, 2009).

Research Needed to Accommodate the Advancement of General Education Research

For a long time, the preoccupation of gifted education has been to determine who is gifted and how to serve their putative "needs" (as if they have the same needs), rather than how to provide authentic learning experiences and help

students advance their knowledge and skills to the next level of which they are capable. Many recent research studies in general education that focused on evoking students' higher order thinking skills with advanced technologies may provide some inspiration for gifted education research. For example, Dunleavy, Dede, and Mitchell (2009) involved students in real settings of historical events or environmental investigations that are augmented by computer-generated sensory input through carrying handheld devices such as smart phones. It will be interesting to put gifted students in these settings and investigate how they interact with the technology and the environment and advance their knowledge and skills. Another technology-based educational game worth exploring is Quest Atlantis, in which students can use avatars to perform inquiry activities (known as "quests") on ecology in a 3D virtual, multiuser environment (Livingstone, Kemp, & Edgar, 2008). It will be valuable to introduce this game to the gifted students, and analyze how they develop a better understanding of the interconnected ideas they are exposed to, and build knowledge through communicating with people who have different concerns, values, and beliefs about the world.

SUMMARY AND CONCLUSION

In this article, we present a conceptual framework of how technology use can enable, enhance, and transform gifted education. The enabling function of technology increases the capacity of gifted education to reach out to not only a larger number of gifted students but also a more diverse range of talented students for their further advancement. The enhancement function of technology increases the quality of services provided by gifted education through more tailored, authentic learning experiences and better social, pedagogical, and technical support. The transformation function of technology reflects a qualitative shift from the cumulated enabling and enhancing effects of technology use in the way gifted education is delivered and received. We argue that any technological innovations are means to an end and thus in and of themselves will not create changes. Gifted education as a field needs to shift to a more contextual, developmental approach (Dai & Renzulli, 2008) and embrace a growth mindset rather than a fixed mindset (Dweck, 1999). It needs to situate students in this global, high-tech knowledge age, taking full advantage of technology innovations in education (Bereiter, 2002; Collins & Halverson, 2009; Zhang, 2012). Only in this way can gifted education fully participate in and benefit from the social and scientific dialogue of changes in education. Technological innovations are a distinct part of this ongoing dialogue that often serves as an engine for educational innovation. These changes fundamentally influence the way we can think about how gifted education can be fashioned or refashioned to achieve its goal of excellence in various valued lines of human activity. How we seize this opportunity to move gifted education forward is a task ahead of educators in the field. More innovative practices of using technology in gifted education are urgently needed, and more systematic, in-depth research is needed to move this field forward. We hope that this enable, enhance, and transform framework can be a preliminary step in that direction.

NOTES

1. For the readers' information, following are a sample of websites that may be used for nurturing creativity and critical thinking skills in gifted education: Creativity Web (http://members.optusnet.com.au/charles57/Creative/index2.html), the Center for Creative Learning (http://www.creativelearning.com/), Destination Imagination (http://www.idodi.org/), the Future Problem-Solving Program (http://www.fpspi.org/), and the Center for Critical Thinking (http://www.criticalthinking.org/).
2. For instance, Siegle (2005) listed some websites for sharing products, such as International Kids Space (http://www.kids-space.org), which allows students to display their artwork and writing, and ThinkQuest (http://www.thinkquest.org), in which teams of students and teachers can build websites on educational topics, get these websites published on internet and scored by visitors. In the Globe Program (http://www.globe.gov/fsl/welcome.html), students can collect environmental data from their community and report it through the Internet and then collaborate with scientists and students around the world by creating maps and graphs from the interactive global data set.

REFERENCES

Adams, C. M., & Cross, T. L. (1999). Distance learning opportunities for academically gifted students. *Journal of Secondary Gifted Education*, *11*, 88–96.

Baldus, C. M., Assouline, S. G., Croft, L. J., & Colangelo, N. (2009). The Iowa Online Advanced Placement Academy: Creating access to excellence for gifted and talented rural students. In L.V. Shavinina (Ed.), *International handbook on giftedness* (pp. 1225–1234). New York, NY: Springer.

Barab, S., Zuiker, S., Warren, S., Hickey, D., Ingram-Goble, A., Kwon, E. J., . . . Herring, S. C. (2007). Situationally embodied curriculum: Relating formalisms and contexts. *Science Education*, *91*, 750–782.

Barron, B. (2006). Interest and self-sustained learning as catalysts of development: A learning ecology perspective. *Human Development*, *49*, 193–224.

Belcastro, F. P. (2005). Applications of electronic technology to rural gifted students who are blind or visually impaired. *Information Technology and Disabilities, 11*(1). Retrieved from http://people.rit.edu/easi/itd/itdv11n1/belcast.htm

Bereiter, C. (2002). *Education and mind in the knowledge age*. Mahwah, NJ: Lawrence Erlbaum.

Bergen, D. (2001). Differentiating curriculum with technology-enhanced class projects. *Childhood Education*, *78*(2), 117–118.

Besnoy, K. (2007). Creating a personal technology improvement plan for teachers of the gifted. *Gifted Child Today*, *30*(4), 44–49.

Borkowski, J. G., & Peck, V. A. (1986). Causes and consequences of metamemory in gifted children. In R. J. Sternberg & J. E. Davidson (Eds.), *Conceptions of giftedness* (pp. 182–200). Cambridge, England: Cambridge University Press.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.

Bruce, B. C., & Levin, J. A. (1997). Educational technology: Media for inquiry, communication, construction, and expression. *Journal of Educational Computing Research*, *17*(1), 79–102.

Clark, L. (2005). Gifted and growing. *Educational Leadership*, *63*(3), 56–60.

Collins, A. M., & Halverson, R. (2009). *Rethinking education in the age of technology: The digital revolution and the schools*. New York, NY: Teachers College Press.

Cross, T. L. (2004a). Social/emotional needs: Technology and the unseen world of gifted students. *Gifted Child Today*, *27*(4), 14–15. doi:10.4219/gct-2004-153

Cross, T. L. (2004b). Technology and the unseen world of gifted students. *Gifted Child Today*, *27*(4), 14–63.

Cyr, S. (2004). Can distance learning meet the needs of gifted elementary math students? *Gifted Child Today*, *27*(2), 42–51.

Dai, D. Y., & Coleman, L. J. (2005). Epilogue: Conclusions and implications for gifted education. *Journal for the Education of the Gifted*, *28*(3–4), 374–388. doi:10.4219/jeg-2005-336.

Dai, D. Y., & Renzulli, R. S. (2008). Snowflakes, living systems, and the mystery of giftedness. *Gifted Child Quarterly*, *52*, 114–130.

Dixon, F., Cassady, J., Cross, T., & Williams, D. (2005). Effects of technology on critical thinking and essay writing among gifted adolescents. *Journal of Secondary Gifted Education*, *16*, 180–189.

Dove, M. K., & Zitkovich, J. A. (2003). Technology driven group investigations for gifted elementary students. *Information Technology in Childhood Education Annual*, *2003*(1), 223–241.

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education and Technology*, *18*(1), 7–22. doi:10.1007/s10956-008-9119-1

Dweck, C. S. (1999). *Self theories: Their role in motivation, personality, and development*. Philadelphia, PA: Psychology Press.

Eckstein, M. (2009a). Enrichment 2.0: Gifted and talented education for the 21st century. *Gifted Child Today*, *32*(1), 59–63.

Eckstein, M. (2009b). The gifted kids network. *Gifted Child Today*, *32*(2), 20–28.

Eiselen, C. H., & Fox, M. M. (1990). Online database searches in gifted student independent study: Investigating the limits. *Roeper Review*, *13*, 45–52.

Feldhusen, J. F. (1992). *TIDE: Talent identification and development in education*. Sarasota, FL: Center for Creative Learning.

Gadanidis, G., Hughes, J., & Cordy, M. (2011). Mathematics for gifted students in an arts- and technology-rich setting. *Journal for the Education of the Gifted*, *24*, 397–433.

Garrison, D., Anderson, T., & Archer, W. (2000). Critical inquiry in a text-based environment: Computer conferencing in higher education. *The Internet and Higher Education*, *2*(2–3), 87–105.

Hertzog, N. B. (2009). The arbitrary nature of giftedness. In L. Shavinina (Ed.), *International handbook on giftedness* (pp. 205–214). New York, NY: Springer.

Livingstone, D., Kemp, J., & Edgar, E. (2008). From multi-user virtual environment to 3D virtual learning environment. *Association for Learning Technology Journal*, *16*(3), 139–150.

McKinnon, D. H., & Patrick Nolan, C. J. (1999). Distance education for the gifted and talented: An interactive design model. *Roeper Review*, *21*, 320–325.

McKinnon, D. H., & Patrick Nolan, C. J. (2002). Electronic technology and its use with rural gifted students. *Roeper Review*, *25*, 14–16.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*, 1017–1054.

Mulrine, C. F. (2007). Creating a virtual learning environment for gifted and talented learners. *Gifted Child Today*, *30*(2), 37–40.

Ng, W., & Nicholas, H. (2007). Technology and independent learning. *Roeper Review*, *29*, 190–196.

Olson, A. (2005). Improving schools one student at a time. *Educational Leadership*, *62*(5), 37–40.

Olszewski-Kubilius, P. (2005). The Center for Talent Development at Northwestern University: An example of replication and reformation. *High Ability Studies*, *16*(1), 55–69. doi:10.1080/13598130500115254

Pyryt, M. C. (2009). Recent developments in technology: Implications for gifted education. In L. V. Shavinina (Ed.), *International handbook on giftedness* (pp. 1173–1180). New York, NY: Springer.

Ravaglia, R., Suppes, P., Stillinger, C., & Alper, T. M. (1995). Computer-based mathematics and physics for gifted students? *Gifted Child Quarterly*, *39*, 7–13.

Renzulli, J. S. (1977). *The enrichment triad model: A guide for developing defensive programs for the gifted and talented*. Mansfield Center, CT: Creative Learning Press.

Renzulli, J. S. (1986). The three-ring conception of giftedness: A developmental model for creative productivity. In R. J. Sternberg & J. E. Davidson (Eds.), *Conceptions of giftedness* (pp. 53–92). Cambridge, England: Cambridge University Press.

Renzulli, R. S., & Reis, S. M. (2009). A technology-based application of the schoolwide enrichment model and high-end learning theory. In L. Shavinina (Ed.), *International handbook on giftedness* (pp. 1203–1223). New York, NY: Springer.

Richey, R. (2008). Reflections on the 2008 AECT definitions of the field. *TechTrends*, *52*(1), 24–25.

Russel, M., Bebell, D., O'Dwyer, L., & O'Connor, K. (2003). Examining teacher technology use: Implications for preservice and inservice teacher preparation. *Journal of Teacher Education*, *54*, 297–310.

Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 97–115). Cambridge, England: Cambridge University Press.

Schroth, S. T., Helfter, J. A., & Dammers, R. (2009). Using technology to assist gifted children's musical development. *Gifted Child Today*, *32*(2), 54–61.

Shaunessy, E. (2005). Assessing and addressing teachers' attitudes toward information technology in the gifted classroom. *Gifted Child Today*, *28*(3), 45–53.

Shavinina, L. V. (2009) High intellectual and creative educational multimedia technologies for the gifted. In L. V. Shavinina (Ed.), *International handbook on giftedness* (pp. 1181–1202). New York, NY: Springer.

Shermis, M. D., Fulkerson, J., & Banta, T. W. (1996). Computerized adaptive math tests for elementary talent development selection. *Roeper Review*, *19*, 91–95.

Shore, B. M. (2000). Metacognition and flexibility: Qualitative differences in how gifted children think. In R. C. Friedman & B. M. Shore (Eds.), *Talents unfolding: Cognition and development* (pp. 167–187). Washington, DC: American Psychological Association.

Siegle, D. (2004). The merging of literacy and technology in the 21st century: A bonus for gifted education. *Gifted Child Today*, *27*(2), 32–35.

Siegle, D. (2005). Six uses of the Internet to develop students' gifts and talents. *Gifted Child Today*, *28*(2), 30–36.

Siegle, D. (2009). Literacy in the 21st century: The fourth R-video recording. *Gifted Child Today*, *32*(2), 14–19.

Stanley, J. (2000). Helping students learn only what they don't already know. *Psychology, Public Policy, and the Law*, *6*, 216–222.

Subhi, T. (1999a). Attitudes toward computers of gifted students and their teachers. *High Ability Studies*, *10*(1), 69–84.

Subhi, T. (1999b). The impact of LOGO on gifted children's achievement and creativity. *Journal of Computer Assisted Learning, 15*(2), 98–108.

Technology. (n.d.). In Merriam-Webster's online dictionary. Retrieved from http://mw1.merriam-webster.com/dictionary/technology

Tomlinson, C. A., & Callahan, C. M. (1992). Contributions of gifted education to general education in a time of change. *Gifted Child Quarterly*, *36*, 183–189.

Twining, P. (2002), Conceptualising computer use in education: Introducing the Computer Practice Framework (CPF). *British Educational Research Journal*, *28*(1), 95–110.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds.). Cambridge, MA: Harvard University Press.

Wallace, P. (2005). Distance education for gifted students: Leveraging technology to expand academic options. *High Ability Studies*, *16*(1), 77–86.

Wassermann, S. (2001). Curriculum enrichment with computer software: Adventures in the trade. *Phi Delta Kappan*, *82*, 592–597.

Wu, Y., & Ma Z. (2009). Principles and practices report on online enrichment and extension for the gifted and talented. *Canadian Social Science*, *5*, 112–118.

Ybarra, L. (2005). Beyond national borders: the Johns Hopkins University Center for Talented Youth reaching out to gifted children from throughout the world. *High Ability Studies*, *16*(1), 15–26.

Zhang, J. (2012). Knowledge construction in a technological platform. In D. Y. Dai (Ed.), *Design research on learning and thinking in educational settings: Enhancing intellectual growth and functioning* (pp. 201–224). New York, NY: Routledge.

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