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INTERNATIONAL REVIEW

Trends of educational technology research: more than a decade of international research in six SSCI-indexed refereed journals

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Abstract This study applied text mining methods to examine the abstracts of 2,997 international research articles published between 2000 and 2010 by six journals included in the Social Science Citation Index in the field of Educational Technology (EDTECH). A total of 19 clusters of research areas were identified, and these clusters were further analyzed in terms of productivity by country and by journal. The analysis revealed research areas with rising trends, stable status, and low attention. This study also identified areas of research emphasis by journal and research strength by country. A discussion of results through the lens of Critical Theory of Technology is also included. The authors hope to inform the EDTECH community about the trends of EDTECH research on topics and regions of research contributions. The authors also believe that such examination of trends can help facilitate fruitful discussions of directions for future research, and possible international collaboration across various geographical regions.

Keywords Educational technology · International research trends · Text mining · SSCI

Introduction

The rapid advancement of emerging technologies presents educators and scholars around the globe with unprecedented opportunities to use these technologies to improve teaching and learning. At the same time, the need to explore how educational technologies can effectively support teaching and learning has resulted in the exponential growth of research articles

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published in peer-reviewed journals in the field of Educational Technology (EDTECH hereafter). EDTECH's definition has evolved over the years as a variation of ways of dealing with learning processes (Ely 1963), a conceptual framework (Davies and Schwen 1971), theory and practice (Seels and Richey 1994), and the latest study and ethical practices of dealing with technological processes and resources (AECT 2007, in Januszewski and Molenda 2007).

In the past, there has been an effort to identify research trends in technology-based learning environments (Winn 2002; Mihalca and Miclea 2007; Ross, Morrison and Lowther 2010). However, these efforts did not take a comprehensive view beyond learning environments. Winn (2002) and Mihalca and Miclea (2007) failed to factor in international research trends on educational technology. This is void that requires research to inform the various foci and strengths of international contributions. While informative, both review papers divided the research of educational technology broadly by "ages" and supported their categorization by selecting relevant literature. Neither review applied a method of data collection to systematically examine the actual available "data" (i.e., the published articles). More recently, Hung (2012) studied the trends of e-learning research by examining the abstracts from over 600 refereed journal articles and proceedings using text mining methods and bibliometrics. Hung's study systematically collected journal articles and provided a longitudinal view of these articles. However, his study focused mainly on e-learning without a comprehensive view of the EDTECH field as a whole.

We selected six important refereed journals in EDTECH with rich representation of international contributing authors. The six journals are all included in the Social Science Citation Index (SSCI) and rank Top 50 in SSCI. The period of time of the selected articles spans 11 years, from 2000 to 2010. Our purpose was to include a long enough timespan so that readers could see possible transitions and changes in EDTECH research which might reveal directions for future research, but not too long a period, so that the paper can still help focus on more recent changes. We hope that this research can inform the EDTECH community about recent trends of EDTECH research on topics, domains, and regions of research contributions. We believe that such examination of trends can help facilitate fruitful discussions of directions for future research, and possible international collaboration across various geographical regions.

Review of educational technology research

Review research helps scholars identify research trends in selected fields or on selected topics. In general, review research can be conducted using the following methods: (a) selective article review (e.g., Simonson, Schlosser and Orellana 2011; Mihalca and Miclea 2007; Winn 2002); (b) systematic content analysis (e.g., Shih, Feng and Tsai 2008; Lu, Wu and Chiu 2009; Hung 2012; Hung and Zhang 2012; Maurer and Khan 2010); and (c) systematic citation analysis (e.g., Gall et al. 2010; Ozcinar 2009; Uzunboylu, Eriş and Ozcinar 2011).

Selective article review is conducted by discussing author-selected articles. However, scope, data source, and article selection standards were usually not clearly defined. For example, Winn (2002) reviewed self-selected articles and defined the evolution of e-learning into the ages of instructional design, message design, simulation, and learning environments. The author concluded that e-learning research had shifted to discuss learning environments and various learning interactions. However, this conclusion might be subjective without supporting evidence from systematic investigation.

In recent years, systematic content analysis and citation analysis have become the major methods of research review studies. These types of studies usually have well-defined scopes, data sources, and article selection standards. Content analysis reveals research trends through analyzing article content and grouping articles based on their shared characteristics. For example, Shih, Feng and Tsai (2008) investigated trends of cognition research in e-learning. The authors collected 444 articles from five major SSCI educational technology journals during the period from 2001 to 2005. Their major findings showed that "Instructional Approaches," "Learning Environment," and "Metacognition" were the three most popular research topics. With the development of artificial intelligence analysis, content analysis can also be conducted quantitatively using text mining techniques. It saves researchers' time and reading efforts so they can focus on result interpretation and discussion.

Citation analysis has been used in social sciences for investigating research contributions of individuals, institutions, and professional journals (Brown and Gardner 1985). For example, Ozcinar (2009) investigated 758 "instructional design" articles published between 1980 and 2008 and found that 87 % of those articles came from seven countries, with the countries in the Far East being poorly represented.

For the purpose of our study—examining a large number of research articles representing the EDTECH field published between 2000 and 2010, text mining was selected as the research method as it allows for systematic filtering and analysis of large amounts of text data, which is further explained in the next section.

Text mining

Text mining (TM hereafter) or text data mining is the process of analyzing information in large text collections and automatically identifying interesting patterns and relationships in the textual data (Feldman and Sanger 2007). The process is also called *Knowledge Discovery in Databases* (KDD) which involves extracting high-level knowledge from low-level data (Fayyad et al. 1996).

Traditionally, research trends studies were conducted using content analysis (e.g., Lee, Wu and Tsai 2009). This type of research has the benefit of full-text examination, but also has the drawbacks of time consumption and researcher subjectivity. In contrast, TM allows researchers to process thousands of records and cluster articles based on their content similarity.

In recent years, TM has been adopted to study longitudinal trends of research articles and technical reports (e.g., Kostoff, Koytcheff and Lau 2007; Hung 2012; Hung and Zhang 2012). These articles shared the following characteristics:

a) *Large sample size* Sample size could range from hundreds (Hung 2012; Hung and Zhang 2012) to more than ten thousand (Kostoff et al. 2007).
b) *Exhaustive search* Traditional content analysis methods might focus mostly on selective journals only, while TM enables researchers to extract all related articles from the entire database.
c) *Data source* In order to control data noise and avoid obtaining trivial clusters, TM studies usually utilize abstracts as the major data source.

Method

The data analysis followed the KDD process, including data extraction, data preprocessing, transformation, text mining, and evaluation/interpretation (Fayyad et al. 1996). The subsections below delineate the data analysis we applied by following the KDD model steps.

Data extraction

To prepare for data extraction from the SSCI databases, we selected six representative refereed journals in the EDTECH field, including:

- British Journal of Educational Technology (BJET)
- Computers & Education (C&E)
- Journal of Educational Technology and Society (JETS)
- Educational Technology Research & Development (ETR&D)
- Innovations in Education and Teaching International (IETI)
- Journal of Computer Assisted Learning (JCAL)

These six journals have the following characteristics in common:

- Refereed
- Indexed in Social Science Citation Index (SSCI) (ranked Top 50)
- Strong focus on applying technology for educational purposes
- Positive reputation in the EDTECH field
- International Readership/Authorship
- Published in English

SSCI database stores different types of academic publications such as journal articles, meeting abstracts, proceedings papers, and book reviews. In this paper, our target data were limited to journal articles only. Table 1 below provides a more detailed breakdown of characteristics by journal.

Among the six journals, we included JETS for 8 years and IETI for 9 years because the former was included in SSCI starting in 2003 and the latter in 2002.

Data preprocessing

The data of the following variables were collected and analyzed with TM-generated clusters for revealing research trends: publication year, journal title, number of authors, number of pages, first author's country, and first author's institution. These variables are indicators commonly used in library science (Thelwall 2008). Other variables such as issue number, article type, Digital Object Identifier (DOI), language, and keywords were removed from the data set. Transformation in data mining refers to aggregating/transforming data to form new variables for meaningful analysis. In this study, "number of authors" and "number of pages" were the variables aggregated from the collected data. For example, the article, Delwiche 2006. Massively multiplayer online games (MMOs) in the new media classroom. *Educational Technology & Society, 9*(3), 160–172., has one author and 13 pages.

Analytic tool

The software, SAS (Institute Inc., Cary, NC, USA) Text Miner 4.2 was used to conduct text mining in this study, and grouped research articles based on abstract similarities. A list of "stop words" was generated by the software and the authors of the present study to eliminate obvious non-technical words (e.g., almost, along, herein, consequently), and to keep meaningful, domain-related words. SAS Text Miner then compared abstract similarity by using domain-related words and grouped similar articles into clusters. Finally, all clusters were agglomerated into a hierarchical tree structure based on agglomerative

Table 1 A summary of the six journals selected

Journal title	Acronym	Time range of articles included	Years of articles included for analysis (years)	2009 ISI journal citation reports® ranking: education & educational research (139 journals)*
British Journal of Educational Technology	BJET	2000–2010	11	32
Computers & Education	C&E	2000–2010	11	9
*Journal of Educational Technology and Society***	JETS	2003–2010	8	37
Educational Technology Research & Development	ETR&D	2000–2010	11	34
Innovations in Education and Teaching International	IETI	2002–2010	9	50
Journal of Computer Assisted Learning	JCAL	2000–2010	11	27

* (Thomson Reuters 2009)

** This journal grants free full access to all its articles

clustering algorithm (Jain, Murthy and Flynn 1999) to form a hierarchical taxonomy structure.

Interpretation/evaluation

Data interpretation/evaluation was executed through: (1) examining the hierarchical taxonomy structure of research areas; (2) sampling and reviewing articles in respective research areas; (3) triangulating professional knowledge of research areas among the researchers of this study. The results of interpretation/evaluation are reported in the Results and Discussion and conclusion sections of this paper.

Results

Number of published articles per year

Figure 1 shows the number of articles published from 2000 to 2010. The solid lines represent the numbers of published articles from each of the six individual journals each year, and the dashed line indicates the total numbers of published articles across six journals each year. The following trends were revealed in Fig. 1:

- The total numbers of EDTECH research articles published each year showed a rising trend during the 11 years. In addition, the growth in the number of articles can be

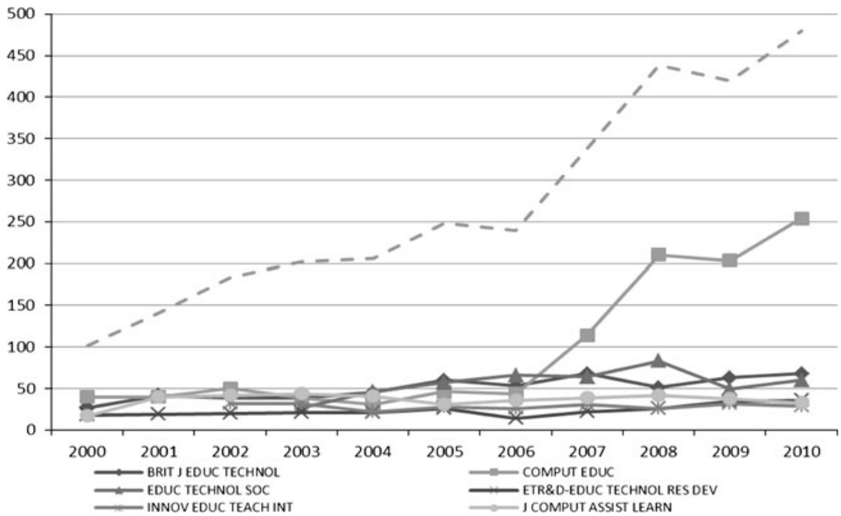

Fig. 1 Numbers of articles published by journal yearly from 2000 to 2010 (The *dashed line* shows the total number of articles published yearly by the six journals.)

divided into two stages: 2000–2005 (compound growth rate 19.45 %) and 2006–2010 (compound growth rate 19.04 %).

- All six journals increased the number of published articles during the first stage, while the growth during the second stage mainly came from Computers and Education (C&E). It showed substantial increase in numbers of published articles—from 2007 to 2010, each year there were two to five times as many as the number in 2006. The total number (dashed) line also showed a similarly increasing trend to that of Computers and Education.

Trends in average length of articles

Figure 2 revealed average page numbers per article across six journals from 2000 to 2010. The following trends are shown in Fig. 2:

- Most journals published articles of 10–15 pages.
- ETR&D published 44.58 % more pages by average than did the other five journals.
- The articles published in C&E showed a decreasing trend regarding number of pages with 9.94 % compound rate (see Fig. 2), which might also allow for inclusion of more articles in each issue, hence more articles each year (see Fig. 1).

It is worth noting that ETR&D had a stark increase of average pages per article from 14.5 pages in 2005 to 24.2 pages in 2006. Based on the responses from the ETR&D editors regarding our observation of this increase, they believed the published articles could just happen to be longer in 2006 since ETR&D's guidelines for submission have not changed much (M. Spector, personal communication, November 2, 2012; M. Hannafin, personal communication, November 2, 2012). The editors also mentioned that ETR&D has gone through layout changes during the period we reported, which could affect page count (M. Spector, personal communication, November 2, 2012). Therefore, when comparing the averaged numbers of pages across journals, researchers should use caution with the

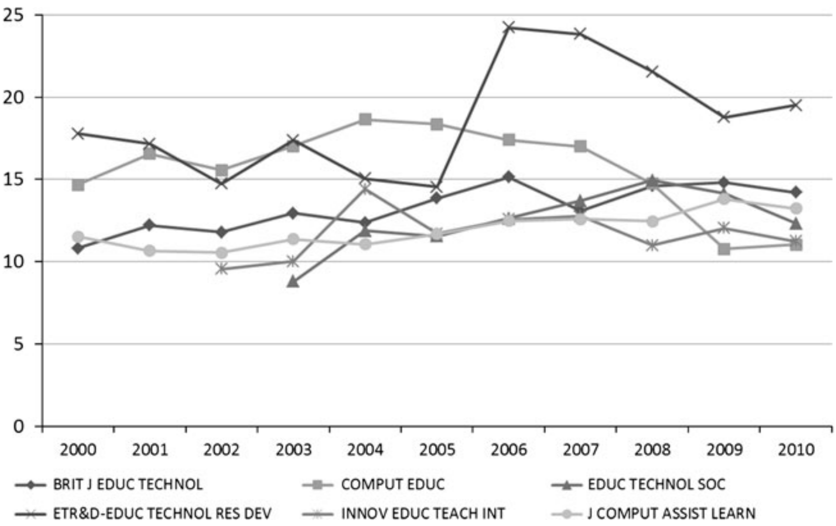

Fig. 2 Average page numbers per article by journal yearly from 2000 to 2010

implications of the data since different journals used different page layout (M. Hannafin, personal communication, November 2, 2012).

Trends in country productivity of articles by journal

Figure 3 shows the results of individual journal publications by country based on the first author's affiliation. The following trends are revealed in Fig. 3 and summarized below regarding top countries of first authors in each journal. If the first country has twice as many articles as the second country, only the first country was listed. If not, both the first and the second countries were listed.

- BJET and IETI: England;
- ETR&D: USA;
- C&E and JCAL: Taiwan and USA;
- JETS: Taiwan and USA.

Taxonomy of EDTECH research

Figure 4 shows the results of clustering analysis. Using this method, we classified articles into a hierarchical structure based on similarity of abstracts. A four-level, 19-cluster hierarchical structure was generated through clustering analysis. These clusters were interpreted by three experts with 27 years of combined EDTECH research experience to ensure inter-rater reliability (Flem, McCracken and Carran 2004).

As illustrated in Fig. 4, beginning at the rightmost column, all articles were divided into 19 clusters (CL1-CL19), and those clusters were then aggregated into higher-level groups and domains. The following are the list of 19 clusters with their cluster names and example articles.

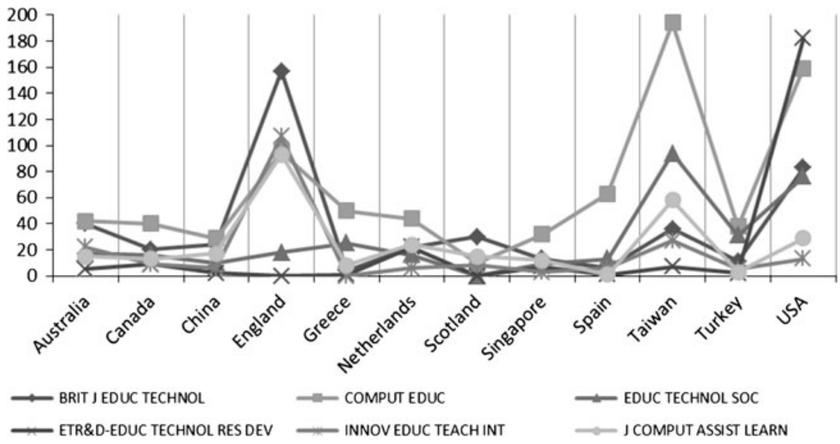

Fig. 3 Country productivity of EDTECH refereed articles by journal between 2000 and 2010

- CL1 (272 articles; 9 % of all sampled articles) includes studies on issues of **Macro View of Technology Integration**. Example article: *Systems limitations hamper integration of accessible information technology in northwest U.S. K-12 schools* (Wisdom et al. 2007).
- CL2 (495 articles; 17 %) includes studies on **Macro View of Online Learning**. Example article: *Educational technology at a crossroads: Examining the development of the academic field in Canada* (Luppicini 2008).
- CL3 (62 articles; 2 %) includes studies on **E-learning in Higher Education** Example article: *Who is responsible for e-learning success in higher education? A stakeholders' analysis* (Wagner, Hassanein and Head Wagner et al. 2008).
- CL4 (78 articles; 3 %) includes studies on **Educational Games**. Example article: *Massively multiplayer online games (MMOs) in the new media classroom.* (Delwiche 2006)
- CL5 (167 articles; 6 %) includes studies on **Technology-assisted Learning**. Example article: *Variability in reading ability gains as a function of computer-assisted instruction method of presentation* (Johnson, Perry and Shamir 2010).
- CL6 (46 articles; 2 %) includes studies on finding how **Learning Styles** influence learning. Example article: *Web-based learning programs: Use by learners with various cognitive styles* (Chen 2010).
- CL7 (39 articles; 1 %) includes studies on **Technology Adoption**. Example article: *Modeling technology acceptance in education: A study of pre-service teachers* (Teo 2009).
- CL8 (120 articles; 4 %) includes studies on **Attitudes toward Technology**. Example article: *The evaluation of the student teachers' attitudes toward Internet and democracy* (Oral 2008).
- CL9 (100 articles; 3 %) includes studies on **Learning Community**. Example article: *Constructing a community of practice to improve coursework activity* (Chang, Chen and Li 2008).
- CL10 (255 articles; 9 %) includes studies on **Instructional Design**. Example article: *Enhancing instructional design efficiency: Methodologies employed by instructional designers* (Roytek 2010).

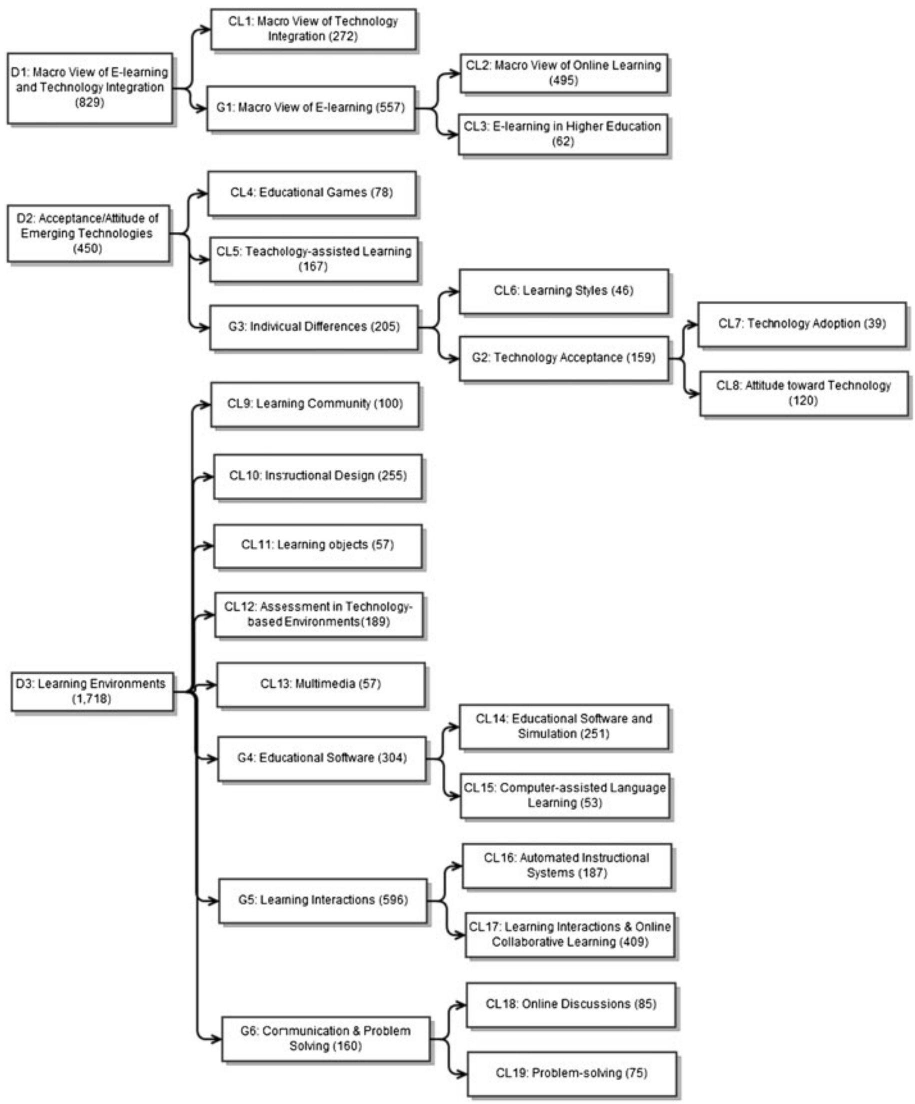

Fig. 4 Cluster tree of major research topics (*D-Domain* top level, *G-Group* middle-level, *CL-Cluster* bottom level)

- CL11 (57 articles; 2 %) includes studies on **Learning Objects**. Example article: *Learning objects in practice: The integration of reusable learning objects in primary education* (Cameron and Bennett 2010).
- CL12 (189 articles; 6 %) includes studies of **Assessment in Technology-based Environments**. Example article: *Constructive multiple-choice testing system* (Park 2010).
- CL13 (57 articles; 2 %) includes studies related to **Multimedia**. Example article: *iTunes University and the classroom: Can podcasts replace Professors?* (McKinney, Dyck and Luber McKinney et al. 2009).

- CL14 (251 articles; 8 %) includes studies on **Educational Software and Simulation**. Example: *Enhancing the learning experience of undergraduate technology students with LabVIEW ™ software* (Tiernan 2010).
- CL15 (53 articles; 2 %) includes studies on **Computer-Assisted Language Learning** (CALL). Example article: *Ethical issues in Computer-Assisted Language Learning: Perceptions of teachers and learners* (Wang and Heffernan 2010).
- CL16 (187 articles; 6 %) includes studies on developing **Automated Instructional Systems**. Example article: *Development of a reading material recommendation system based on a knowledge engineering approach* (Hsu, Hwang and Chang 2010).
- CL17 (409 articles; 14 %) includes studies on **Learning Interactions and Online Collaborative Learning**. Example article: *Using jigsaw and case study for supporting online collaborative learning* (Pozzi 2010).
- CL18 (85 articles; 3 %) includes studies in **Online Discussions**. Example article: *Student-facilitators' roles in moderating online discussions* (Wang 2008).
- CL19 (75 articles; 3 %) includes studies on **Problem-solving**. Example article: *The interactions between problem solving and conceptual change: System dynamic modeling as a platform for learning* (Lee 2010).

The following is a list of "groups" (superordinate of clusters) of topics identified in this review research:

- G1 (CL2 + CL3; 557 articles): studies on **Macro View of E-learning**.
- G2 (CL7 + CL8; 159 articles): studies on **Technology Acceptance**.
- G3 (CL6 + G2; 205 articles): studies on **Individual Differences**.
- G4 (CL14 + CL15; 304 articles): studies on **Educational Software**.
- G5 (CL16 + CL17; 596 articles): studies on **Learning Interactions**.
- G6 (CL18 + CL19; 160 articles): studies on **Communication and Problem-solving**.

The following are the three major "domains" (superordinate of "groups") identified in this research, formed by combinations of groups and clusters.

- D1 (CL1 + G1; 829 articles): studies on **Macro View of E-learning and Technology Integration**.
- D2 (G3 + CL4 + CL5; 450 articles): studies on **Acceptance/Attitude of Emerging Technologies**.
- D3 (CL9 + CL10 + CL11 + CL12 + CL13 + G3 + G4 + G5; 1,718 articles): studies on **Learning Environments**.

Research trends by topic/area cluster from 2000 to 2010

In this section, clusters in Fig. 5 were further categorized in terms of the trends and average number of published articles by cluster per year, which helps reveal trends as well as research interests of the EDTECH field between 2000 and 2010.

Topics on the rise

The following clusters show a rising trend in terms of the number of published papers. Each cluster has more than 15 articles published per year.

- CL1: Macro view of technology integration (average 25 articles/year)
- CL2: Macro view of online learning (average 45 articles/year)

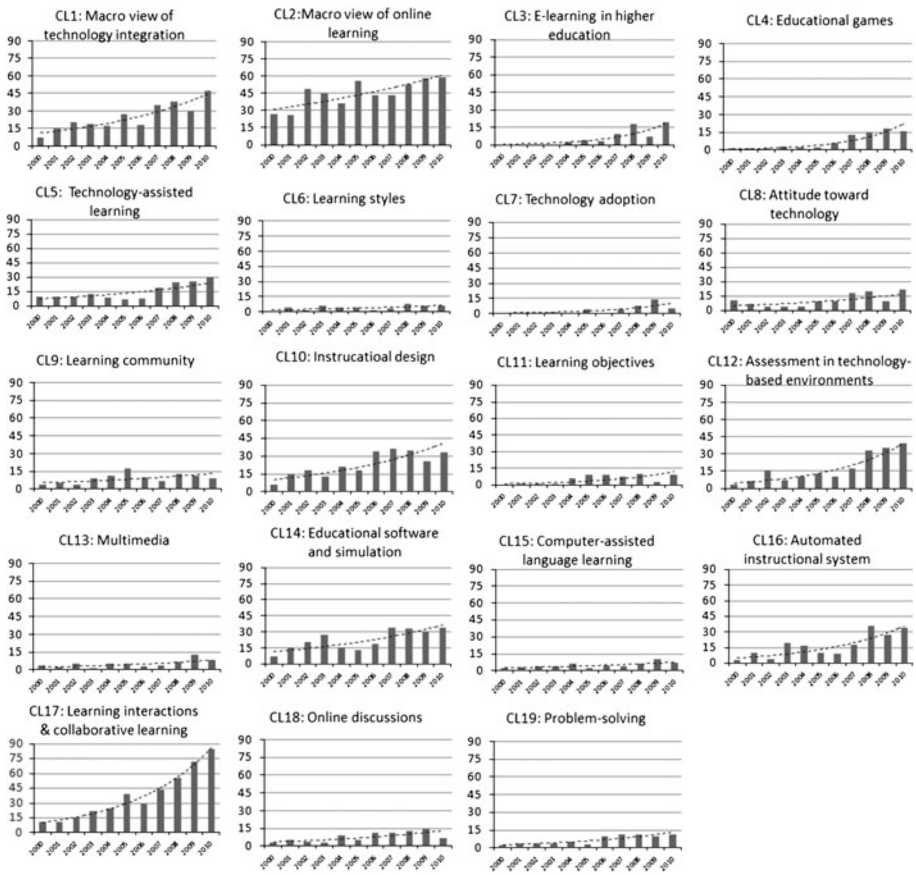

Fig. 5 Research trends by cluster from 2000 to 2010

- CL10: Instructional Design (average 23 articles/year)
- CL12: Assessment in Technology-based Environments (average 17 articles/year)
- CL14: Educational Software and Simulation (average 23 articles/year)
- CL16: Automated Instructional Systems (average 17 articles/year)
- CL17: Learning Interactions and Online Collaborative learning (average 37 articles/year)

Stable topics

There have been clusters that are relatively stable and increasing slightly. Articles in the following clusters have been published continuously from 2000 to 2010 and have shown slight increase in terms of the number of articles published each year, but all averaged no more than 15 articles published per cluster each year.

- CL4: Educational Games (average 7 articles/year)
- CL5: Technology-assisted Learning (average 15 articles/year)
- CL8: Attitude toward Technology (average 11 articles/year)

- CL9: Learning Community (average 9 articles/year)
- CL18: Online Discussions (average 8 articles/year)
- CL19: Problem-Solving (average 7 articles/year)

"Cold" topics There is no cluster showing a decreasing trend. Instead, articles in the following clusters have been published continuously from 2000 to 2010, but all averaged no more than five per cluster each year.

- CL6: Learning Styles (average 4 articles/year)
- CL7: Technology Adoption (average 4 articles/year)
- CL11: Learning Objects (average 5 articles/year)
- CL13: Multimedia (average 5 articles/year)
- CL15: Computer-assisted Language Learning (average 5 articles/year)

Relatively new topic

CL3: E-learning in Higher Education, is a cluster that does not exist between 2000 and 2003, but emerges in 2004 with 2 articles and reaches 19 articles in 2010.

The field of EDTECH may emphasize different research programs in different countries because of the history of the field, education policies and practices, or relevant industries. In the data we examined, the Top 10 countries for publication in the EDTECH field are the USA, England, Taiwan, Australia, Netherlands, Canada, Turkey, Greece, Singapore, and Germany, respectively. To reveal which country published more in which research areas, the Top five productive countries between 2000 and 2010 are included in the analysis. Figure 6 shows the breakdown of the publication numbers by clusters for each of these 5 countries. Looking at Fig. 6, we can identify the research interest/strength in each country included in the analysis.

The USA published most frequently in the following clusters: "Macro View of Online Learning," "Learning Interactions and Online Collaborative Learning," and "Instructional Design." England published most frequently in "Macro View of Online Learning," "Educational Software and Simulation," and "Learning Interactions and Online Collaborative Learning." Taiwan published most frequently in "Automated Instructional Systems," "Learning Interactions and Online Collaborative Learning," and "Assessment in Technology-based learning Environments." Australia published most frequently in "Macro View of Online Learning," "Learning Interactions and Online Collaborative Learning," and "Macro View of Technology Integration." The Top 3 clusters for the Netherlands were "Instructional Design," "Learning Interactions and Online Collaborative Learning," and "Macro View of Online Learning."

Based on these findings, "Learning Interactions and Online Collaborative Learning" is the most popular cluster for these Top five countries. "Macro View of Online Learning" also received a great deal of interest across four of the Top five countries, while Taiwan published relatively little in this cluster. On the other hand, Taiwan published far more than the other four countries in Cluster 16, "Automated Instructional Systems."

The study further examined results across all Top five countries and identified which clusters were dominated by a specific country. The term "dominated," in this context,

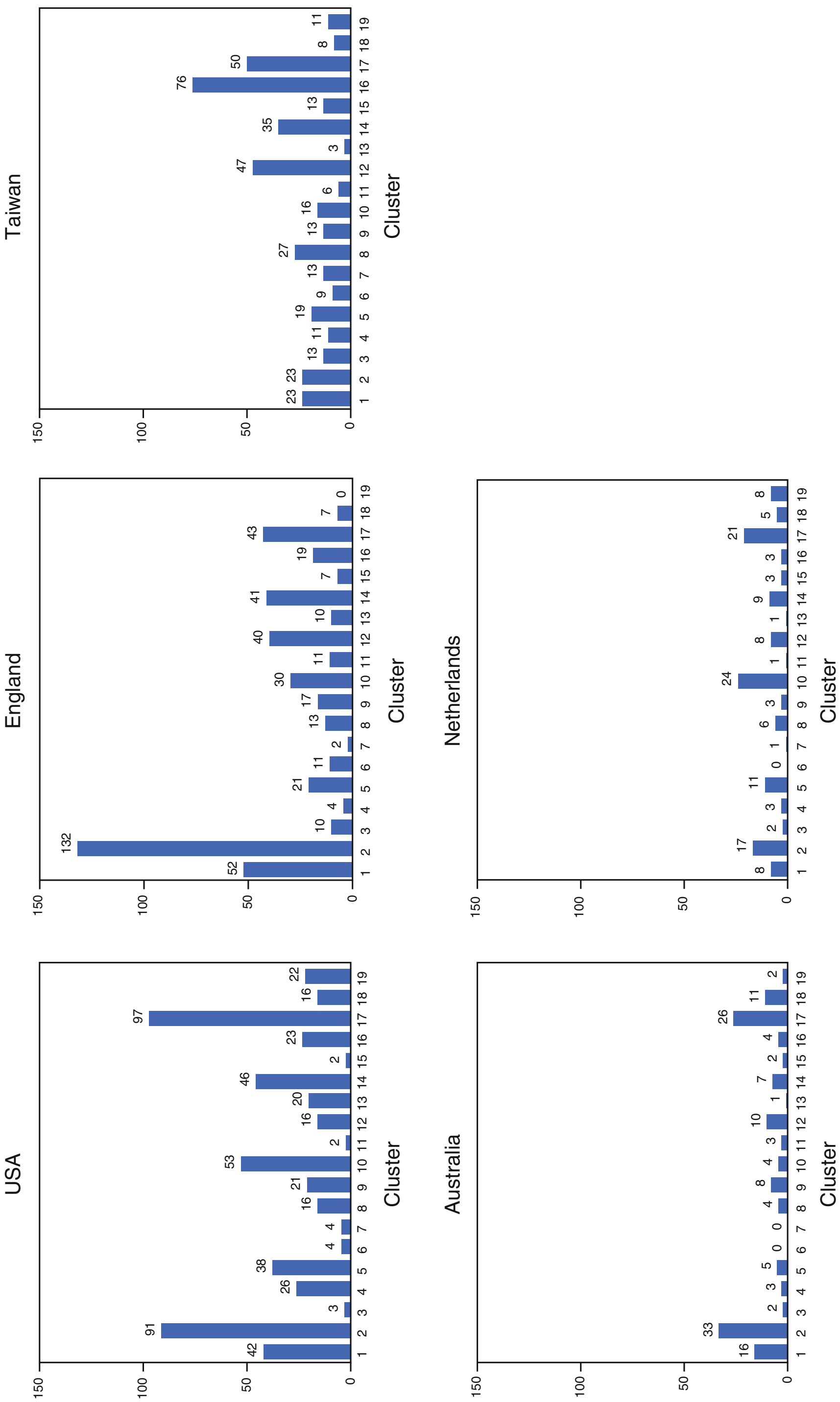

Fig. 6 Numbers of articles by cluster by the Top 5 productive countries: 2000–2010

refers to a country having at least twice the output of the next most productive country. Only five clusters contain a dominant country:

- Educational Game (CL4), Multimedia (CL13), and Problem-Solving (CL19): USA;
- Technology Adoption (CL7) and Automated Instructional System (CL16): Taiwan.

Top clusters published by journals

In our analysis, we identified the Top 3 clusters published by each of the six journals. The results were as follows:

- BJET: Macro View of Technology Integration (CL2), Learning Interactions and Collaborative Learning (CL17), and Instructional Design (CL10); CL2 > CL17 by 61.3 % in terms of the numbers of published articles.
- C&E: Learning Interactions and Collaborative Learning (CL17), Educational Software and Simulation (CL14), and Macro View of Online Learning (CL2); CL17 > CL14 by 29.3 %; CL17 > CL2 by 51.5 %.
- JETS: Macro View of Online Learning (CL2), Learning Interactions and Collaborative Learning (CL17), and Instructional Design (CL10); CL2 > CL17 by 23.3 %.
- ETR&D: Instructional Design (CL10), Learning Interactions and Collaborative Learning (CL17), and Macro View of Technology Integration (CL2); CL10 > CL17 by 9.5 %; CL10 > CL2 by 53.3 %.
- IETI: Macro View of Online Learning (CL2), Assessment in Technology-based Environments (CL12), and Instructional Design (CL10)/Learning Interactions and Collaborative Learning (CL17); CL2 > CL12 by 308 %; CL2 > CL10/CL17 by 386 %.
- JCAL: Macro View of Online Learning (CL2), Learning Interactions and Collaborative Learning (CL17), and Educational Software and Simulation (CL14); CL2 > CL17 by 9 %.

Macro View of Online Learning (CL2) and Learning Interactions and Collaborative Learning (CL17) were among the Top 3 clusters across all six journals. Also, the articles under Macro View of Online Learning were published most in four journals, including BJET, JETS, IETI, and JCAL. Meanwhile, articles under Learning Interactions and Collaborative Learning ranked No.1 in C&E, and No.2 in four journals, including BJET, JETS, IETI, and JCAL.

Overall, Macro View of Online Learning (CL2) superseded Learning Interactions and Collaborative Learning (CL17) in terms of the numbers of papers in most journals, except C&E published 51.5 % more articles on Learning Interactions and Collaborative Learning than on Macro View of Online Learning. It is also worth noting that Instructional Design (CL10) is the most popular cluster in ETR&D rather than Macro View of Online Learning or Learning Interactions and Collaborative Learning. ETR&D published 9.5 % more articles in Instructional Design than the second-place Learning Interactions and Collaborative Learning, and 53.3 % more articles than third-place Macro View of Online Learning. In addition, the vast majority of articles published in IETI were under Macro View of Online Learning, leading the second-place Assessment in Technology-based Learning Environments by 308 % and the third-place Instructional Design by 386 % (see also Fig. 7).

The study applied the same examination of "dominance" in clusters for journals as it did for countries. The term "dominant," once again, refers to a journal having at least

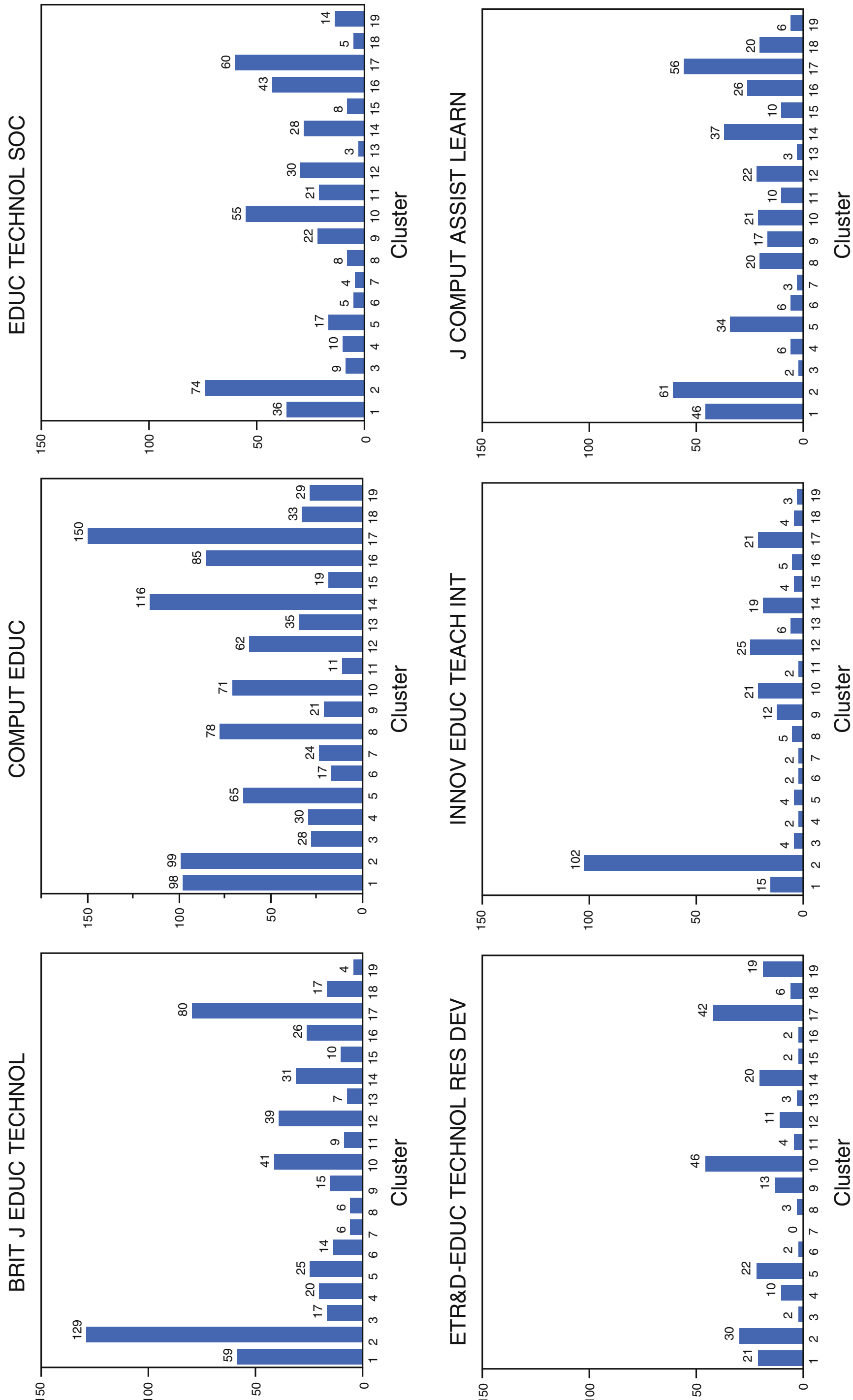

Fig. 7 Numbers of articles by cluster published by the six journals: 2000–2010

twice the output of the next most productive journal by cluster. Computers & Education was the only dominant journal, and dominated in six clusters:

- Educational Games (CL4);
- Technology-assisted Learning (CL5);
- Technology Adoption (CL7);
- Attitude toward Technology (CL8);
- Multimedia (CL13);
- Automated Instructional System (CL16).

Discussion and conclusion

Current era of EDTECH research

After comparing trends across three major domains (D1: Technology Integration; D2: Acceptance/Attitude of Emerging Technologies; D3: Learning Environments), it is found that D1 and D3 have more rising clusters than D2. The results indicate that unless another learning technology causes a similar paradigm shift in learning like the Internet did, Acceptance/Attitude of Emerging Technology is not expected to arouse consistent interest as a hot domain and to yield prolific research in the field of EDTECH. On the other hand, it is the pedagogical use of technology and the effectiveness of instructional/learning strategies in achieving intended learning outcomes that constantly concern researchers and educators in EDTECH and result in prolific research studies. Overall, this study found that Internet technologies constitute the major teaching/learning environments in EDTECH. Within these environments, the studies of various types of interaction and collaborative work contribute to the mainstream of instructional/learning strategies in EDTECH studies. Similar observations were made of previous studies (e.g., Winn 2002). These observations, combined with the data from this study, indicate that EDTECH research is in the era with a focus on learning environments. Winn (2002) defined the evolution of educational technology research into four stages: (1) the age of instructional design, focusing on content; (2) the age of message design, focusing on format; (3) the age of simulation, focusing on interactions; and (4) the new age of research, focusing on learning environments. However, based on the results of this study, instructional design and simulation/interactions are still hot topics in the field.

Through the lens of Critical Theory of Technology

Critical Theory of Technology (Feenberg 2005) is a framework that synthesizes philosophy of technology and constructivist technology studies, aiming to analyze technologies and technological systems at multiple levels. According to Feenberg (2005), technology is a two-sided phenomenon that involves the operator and the object. Where both the former and the latter are human beings, technical action is an exercise of power. Through design, the operator can narrow the range of the object's interests and concerns. When examining the results of this study through the lens of Critical Theory of Technology, the operators that could have potentially shaped the trends of Educational Technology research are identified and some implications for trends in EDTECH research are discussed below.

Government

Taiwan, among the Top 5 prolific countries in EDTECH research, is a special case that showed different research interests compared to the other four countries that showed similar research interest. Research directions in Taiwan have been highly influenced (therefore, narrowed) by government policies. In Taiwan, all e-learning related policies are guided under the framework of National Program for e-Learning which contains three major goals: (a) Improve public welfare; (b) Develop Taiwan's e-learning industry; and (c) Stimulate e-learning research, especially in new learning technologies, methodologies, systems, and tools (Chang, Wang and Chen 2009; Zhang and Hung 2006). Scholars with the aforementioned research foci could more easily obtain grant support from the government (Hung, 2012). The National Program for E-learning framework encourages the development of new learning technologies, and thus, results in the phenomenon that scholars in Taiwan generated large number of publications on the topic of "Automated Instructional Systems." Moreover, Taiwan's government adopted SCI and SSCI as indicators of academic performance (Chang, Wang and Chen 2009). As a result, Taiwan's scholars strive to publish in journals under either indices, and their publication productivity dominates in three (C&E, JCAL, & JETS) of the six journals included for analysis in this study.

However, in actual educational practice, e-learning does not take root in Taiwan due to a variety of reasons. One possible reason may be the widely accessible brick-and-mortar universities for obtaining higher education and thus, less demand on e-learning and distance education. Another possible reason may be related to the current education policies. Based on the regulations by Taiwan's Ministry of Education, online credits cannot exceed one half of total credits toward college graduation (Zhang and Hung 2006; Hung 2012).

Journal

The articles published in a journal and the journal's aim and scope might also play as a role of operator in shaping research trends in the field. For example, Computers & Education increases its number of publications significantly after 2006, which could make research trends of EDTECH sensitive to C&E's topic emphasis and article selection. Based on the results of this study, C&E was the only dominant journal (i.e., having at least twice the number of published articles of the next most productive journal by cluster) among the six journals analyzed in this paper, and dominated in six clusters. It might create an impression that those clusters/topics are "hot", especially for those with relative high numbers of articles in recent years. Also, Computers & Education was ranked 9th (1st in this study) among 139 journals in SSCI. Therefore, researchers' interests can be shaped and greatly narrowed if they want to publish in this top-ranking journal. It is understandable that the published articles in a journal reflect the aims and scope of the journal. Therefore, to a certain extent, the aims and scope of a journal shape and narrow the research interests and directions. However, when one journal has exceptionally higher number of publications than others, the research trends of the field might be distorted and highly correlated with one single journal.

Technology developer

In the history of Educational Technology, new technology development has oftentimes garnered high instructional and research interests. Based on the Critical Theory of Technology, in most cases, the direction of technology development is top–down rather than bottom–up. That means technology developers, as operators, exercise their technical power when they "determine" or "create" needs for end-users when developing new technologies (Feenberg 2005). This one-dimensional technical system (Feenberg 2005) is likely to create resistance among the users, which makes it understandable why the research topic "Attitude toward Technology" was found to be a stable topic in our study. Feenberg suggested democratization of technology could be a solution by opening up technology to a wider range of interests, concerns, and feedback, which could lead to redesigning technology for greater compatibility with the human and natural limits on technical action. While this is some ideal suggestion, it might not happen unless the relationship between the operator and the object can be changed to a great extent. Despite the complexity and scope involved in making democratization of technology possible, the emergence of Web 2.0 technologies can be a good example and a good start of such "ideal" process. The spirit and nature of Web 2.0 generation of technologies encourage participation, creation, and sharing (Hsu, Ching and Grabowski 2009), including getting feedback from the broadly-based users, which constitutes a bottom–up process of feedback loop. Also, Web 2.0 technologies in general pose relatively low technical threshold for users, making it more likely to empower and involve users, which could help level the field for the operator and the object and encourage feedback that helps alleviate resistance.

Limitations

In an effort to control the noise of data analysis, this study selected abstracts as its major data source. Thus, the quality of abstracts could have affected the results. Some key information (such as research methodology) might be absent in the abstract, and thus might not be reflected in the findings of this study. In addition, the authors aimed to perform comparisons on other variables such as international collaboration and interdisciplinary work by analyzing co-authors' countries of origins and affiliations. However, this attempt was not successful because the data extracted from SCI/SSCI database did not provide information with sufficient quality (e.g., some missing values regarding co-authors) to generate meaningful categories. Researchers interested in replicating our study in the future might need to take this aspect into consideration. It is possible that the SCI/SSCI database will improve its data quality on authors' countries of origins and affiliations in the future (i.e., beyond the years examined in this study). If the data quality has not been improved and if authors' countries of origins and affiliations are the foci in future studies, researchers could consider including shorter timeframe (e.g., 5 years), manually categorizing those data, and then analyzing and reporting results by cluster. This adaptation could make the data analysis more manageable.

Future research

Combining citation analysis with the current findings of this study could generate more in-depth knowledge for understanding the trends/themes of EDTECH research. Despite our efforts, we did not analyze every journal in the field of Educational Technology indexed in SSCI. Future research could duplicate our procedures to examine other peer-reviewed journals and examine whether our findings still hold true after cross-examination with text mining and cluster analysis. This research is our first attempt to inform the EDTECH community of research themes by topic and region. We hope our findings can serve as a starting point to help facilitate fruitful discussions of directions for future research, and possibly facilitate more international collaboration across geographical boundaries.

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