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English for Scientific Purposes (EScP): Technology, Trends, and Future Challenges for Science Education

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Abstract To date, the concept of English for Specific Purposes has brought about a great impact on English language learning across various disciplines, including those in science education. Hence, this review paper aimed to address current English language learning in the science disciplines through the practice of computer-assisted language learning to identify the use of learning technologies in science-based literacy. In the literature review, the researchers found that science-based literacy instruction shares many pedagogical aims with English language teaching in terms of reading, writing, listening and speaking, allowing it to be classified as *English for Scientific Purposes* (EScP). To answer the research questions, the researchers conducted the survey by extracting related articles and teaching examples from the Web of Science. In the search procedure, the researchers used the keywords *science* OR *scientific* AND *technolog** OR *comput** in ten selected journals of social science citation index. Only articles which are specified as journal articles rather than other document types were included. After compiling the corpora, the researchers compared the trends, methodologies and results of EScP instruction in science education. The implications of this study include the opportunities, advantages and challenges for EScP instruction in science education to further develop better educational approaches, adopt new technologies, as well as offer some directions for researchers to conduct future studies.

Keywords English for Specific Purposes · Science education · Trend · Scientific literacy

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Introduction

The concept of English for Specific Purposes (ESP) has impacted English language learning across various disciplines bringing more and more scholars to value the practicability of English for bridging the gap between students' general English competence and their ability to apply what they learn in authentic discipline-specific contexts (Cargill et al. 2012; Chiu and Liu 2013; Konttinen 2012; Laborda 2011; Soler 2011; Spence and Liu 2013). As Laborda (2011) points out, "Language for Specific Purposes (LSP) can be defined as the teaching of a language as a second or foreign language for certain groups of students to whom the syllabus, tasks and methodology is especially tailored to their interests and needs" (p. 102). Similarly, Konttinen (2012) illustrates that realizing learners' specific need is the primary idea of English for Specific Purposes, and it can be fulfilled by means of using activities and methodologies relevant to their disciplines (Chiu and Liu 2013). Thus, analyzing students' needs according to their disciplines and backgrounds is the first priority of teaching language learners the target language.

In this paper, the researchers include *English for Scientific Purposes* (EScP) under the scope of English for Academic Purposes (EAP), which indicates students' academic proficiency according to their specific academic discipline. Huhta (2010) provides a classification of EScP

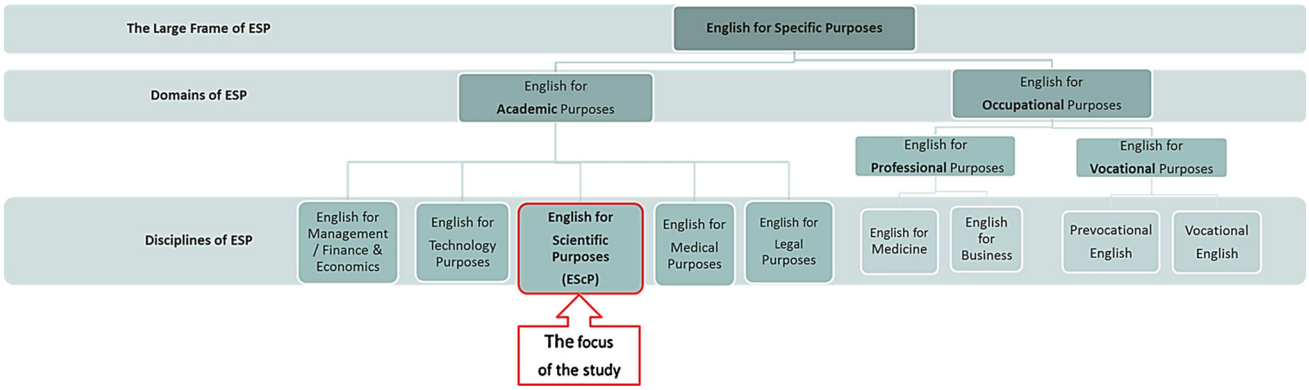

Fig. 1 ESP classification by professional area (adapted from Huhta 2010)

(see Fig. 1) showing English for Science and Technology Purposes as one of the subcategories of EAP.

Definitions

As ESP is used with varying meanings under different situations, it is worth indicating how we use the term in this article. ESP stands for English for Specific Purposes such as English for business, law science and tourism; however, the purpose of the current study is more specific, exploring English language learning in scientific contexts, so we adopt the term English for Scientific Purposes (EScP). To be more specific, EScP refers to both science teaching in an ESP context and Science Literacy Instruction (SLI). Yore and Treagust (2006) mentioned that science literacy in science education is indispensable since it enhances learners to have a better understanding of the specific discourse of scientific writing and promotes critical thinking skills. These skills and knowledge can be furthered if combined with learning technologies (LT). As scientific writing patterns and critical thinking skills are needed in addition to strong language abilities, especially in higher education, non-native speakers of English studying science need to be instructed in both English and SLI. Therefore, it stands to reason that EScP in this article must interweave English language teaching with the content knowledge that is found in SLI. In language teaching, this is known as Content-Based Instruction (CBI) where academic context is taught alongside second language skills simultaneously providing students with the language skills needed to discuss, analyze, report and critique the subject matter (Creese 2005; Butler 2005).

To further clarify the terms used in this paper, the definition of science includes both the natural sciences and the formal sciences. According to the definition provided by the *Journal of Science Education and Technology*, "there are five branches of natural science: astronomy, biology, chemistry, the Earth sciences and physics." As advised, the researchers followed the practical function of science and technology provided by this Journal to search research papers and develop the review study. In addition, based on the classification toward the use of technology in language learning and scientific literacy in terms of locus of control (Liu and Chen 2007; Liu 2008), there are mainly three types of technology that were used in the analysis, including computer-mediated communications (CMC) tools, learning management systems (LMS) and computer-assisted language learning (CALL) programs (Liu and Chen 2007; Liu et al. 2011). Thus, the present literature review used the same classifications.

In terms of the four language skills in ESP contexts, Krajcik and Sutherland (2010) mention:

> Reading, writing, and oral communication are critical literacy practices for participation in a global society. In the context of science inquiry, literacy practices support learners by enabling them to grapple with ideas, share their thoughts, enrich understanding, and solve problems (Krajcik and Sutherland 2010, p. 456).

From this, we can see that language skills play a vital part in helping students enhance their content knowledge, which is the aim of ESP. Likewise, as Snow (2010: 452) claims, to help students understand science, teachers cannot overlook students need to realize the language skills such as writing and discussing science. This is the reason why the current study aims to organize the findings of the previous studies in terms of the four languages skills.

In terms of the ESP learning context, the syllabus, tasks and methodology (Konttinen 2012) are other important issues gaining plenty of attention. Nowadays, applying CALL into course instruction can be seen as an inevitable consequence of the growth of technology in educational contexts. In the current study, we want to explore how EScP is taught in the realm of CALL. As Morgan (2009) asks, "are there some particular aspects of EAP instruction, which are enhanced by the use of computer technology and, if so, what are they? Can the use of computers be

justified when comparing the costs involved to those of hiring extra teachers?'' (p. 94). Regarding the first question, Morgan notes both the success of concordance programs for academic vocabulary and online language learning communities for autonomous learning. However, he issues a caveat regarding the financial costs of software, which must be upgraded periodically and of training teachers on how to use and implement the software. The author concludes that teachers will not be replaced by computers, but teachers who use computers for instructional purposes may replace those who do not, which highlights the need to for professional training with LT.

This paper examines the teaching cases in EScP classes in terms of the four language skills (speaking, listening, reading and writing) and three language study areas (vocabulary, culture and grammar). In this survey, we primarily go through the overall teaching cases without specifying the grades and ages of the language learners since the literature we discuss in this paper deals with students from various grades and the relatively small number of papers on this topic makes a more focused study unfeasible at this point in time. Generally, scientific reading and writing outnumber scientific listening and speaking, and to our surprise, there is was relatively little research in the field over the 5 years. Therefore, alongside the collection of studies regarding implementing technologies into EScP classroom instruction, we also provide the current trends in science instruction without LT in EScP studies in 2008–2012. This will be used to help give some implications for science literacy and CALL in science research and education.

Literature Review

Research Trends Concerning Teachers' Implement of Technology in Science Instruction

According to Higgins and Spitulnik (2008), previous studies relating to applying technologies in science instruction can be divided into two main research areas: first, the influences on teachers' use of technology in inquiry science, which refers to the "accepted norm in the scientific community for solving problems" (Singer et al. 2000, p. 168) and, secondly, evaluating the effects on instructors' professional development.

As Williams et al. (2004) indicate, researchers have explored how technology enhances instructors' in the field of science and many of them gain reflective and mentoring support from the use of technology. Moreover, Higgins and Spitulnik (2008) point out that if we want to improve the state of integrating technologies in education, it is best for researchers and educators to clearly understand how the instructors use technologies in the classroom. Nevertheless, though the review paper by Higgins and Spitulnik (2008) offers great directions for the future scholars and educators, it merely focuses on science instruction without the elements of science literacy and English language teaching (ELT), which leaves a gap in the literature for us to fill.

The Edifications from Previous Studies of Literacy and Science

Stage et al. (2013) mention English Language Arts (ELA), namely literacy, should be combined with target subject learning. For ESP, instruction should be integrated with language and literacy teaching. Stage et al. (2013) provide the following chart (Fig. 2) adopted from Cheuk (2012), and E5 in Fig. 2 shows that science students should acquire well-developed language skills such as reading, writing and speaking in order to demonstrates sound scientific reasoning. Also, S8 in Fig. 2 highlights that when students are exchanging information, there is a need for strong communication skills in terms of listening and speaking. This demonstrates that the four English language skills (reading, writing, listening and speaking) are vital for science instruction.

Furthermore, as Pearson et al. (2010) state, "The integration of literacy practices and inquiry-science education encourages instructional strategies that build on students curiosities about the world and support students in building fundamental literacy skills" (p. 459). They deem that educators have a responsibility to support students to build their scientific English language in writing, reading and communicative skills.

After viewing the literature regarding both trends in science instruction and in literacy and science, we found that there is still limited review research in the field. Moreover, there is a lack of reviews on implementing technologies in the EScP field, which is the primary purpose of this paper. Hence, the three research questions of this study are as follows:

1. What are the primary research trends, methodologies and results in 2008–2012 EScP instruction?
2. What are the major LT in EScP instruction during 2008–2012?
3. What are the opportunities, advantages and challenges for EScP instruction?

Method

To systematically answer the research questions mentioned above, the articles included in our literature review were collected from the database, *Web of Science (WOS)*. The papers included in the study were all published from 2008

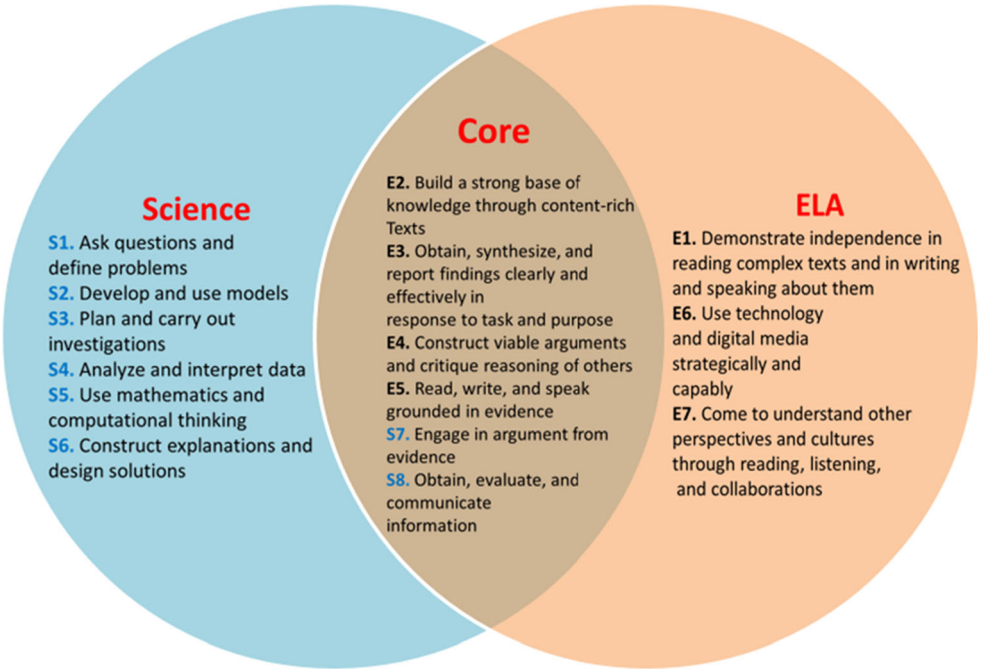

Fig. 2 Relations and convergences in literacy and science (adapted from Cheuk 2012)

Table 1 The 2012 impact factor of the ten selected journals

Journals	Impact factor in 2012
AJET	1.363
CALL	1.020
CAE	2.775
ESP	1.146
ETR&D	1.155
ETS	1.171
LLT	1.379
System	0.692
ReCALL	1.118
TESOL quarterly	0.792

to 2012 from the following ten target journals: *Australasian Journal of Educational Technology* (AJET), *Computer Assisted Language Learning* (CALL), *Computers & Education* (CAE), *English for Specific Purposes* (ESP), *Educational Technology Research & Development* (ETR&D), *Journal of Educational Technology & Society* (ETS), *Language Learning & Technology* (LLT), *System*, *ReCALL* and *TESOL Quarterly*. The reasons that these ten journals were selected include (a) the impact factors (see Table 1), (b) at least 15 years of publication history and (c) duplicable research in the future by other investigators to make a comparison or distinguish the difference. In the search procedure, the researchers used the keywords *science* OR *scientific* AND *technolog** OR *comput** in the ten selected journals from the social science citation index (SSCI) in the WOS. Only articles which are specified as journal articles rather than other document types were included. After compiling the corpora, the researchers compared the trends, methodologies and results of EScP instruction in science education. After the detailed search, a total of 15 papers were found to meet the criteria needed for this review.

Full details of the search procedure are presented in Fig. 3.

The items examined in the study were (a) research purposes, (b) learner demographics, (c) methodology, (d) the use of technology, (e) language learning skills, (f) educational contexts and (g) the outcomes of the studies.

Moreover, there are four dimensions to specifically examine (c) methodology, which include (1) research design trends, (2) challenges of using the methodologies, (3) implications or suggestions for future research designs and (4) the effectiveness and strength of the empirical support. These research challenges can be clarified by adopting the perspective of soft technologies and hard technologies proposed by Liu (2011). According to Liu (2011), soft technologies include instructional techniques, methods and principles, while hard technologies mean both the software and hardware that learners use to acquire knowledge and skills. As for how to examine the effectiveness and strength of the empirical supports, we used an approach provided by Golonka et al. (2014), which examines the strength of the evidence and methodological

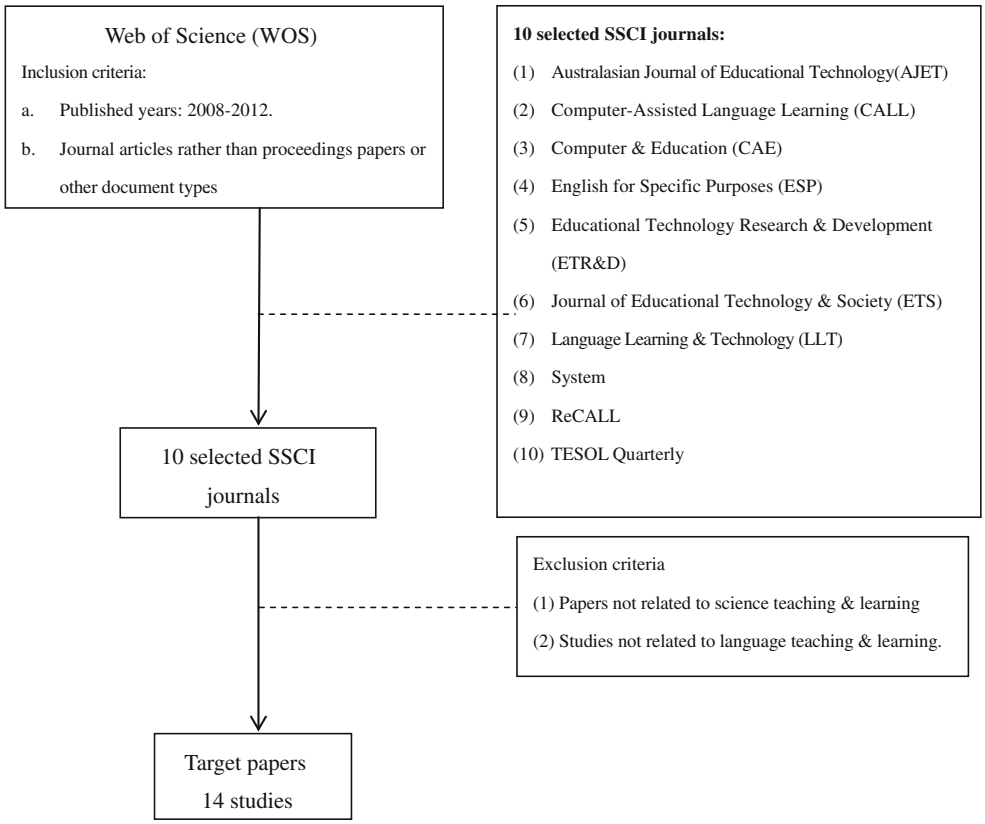

Fig. 3 Search procedures

designs in empirical studies. As Golonka et al. (2014) maintain, there are three distinctions to be made for empirical designs: strong, moderate and weak (as shown in Table 2). The key papers in the current study are analyzed by these criteria.

Results

To systematically answer the research questions, the results were divided into three parts: an analysis of the research trends in EScP instruction and teacher training: the use of LT in EScP; and EScP instructional trends without LT. The results of the first part are provided in Tables 3 and 4. Table 3 is an analysis of studies related to the use of LT in EScP instruction, and Table 4 is an analysis of studies related to the use of LT in EScP teacher training. All nine research papers show positive outcomes for the use of LT in instruction and teacher training.

The Overall Distribution of Research Aims

The distribution of the research aims of the studies gathered in the current literature review was divided into two groups by examining the methodology of each study. As shown in Fig. 4, 57 % (4 studies) of the studies focused on how to enhance science literacy skills including listening, speaking, reading, writing, pronunciation, vocabulary and culture, while 43 % (3 studies) of the literature focused on teacher training in relation to how to implement EScP courses.

Three of the 14 studies were related to LT, while only 5 studies discussed the implications for EScP instructors. Thus, the following parts were divided into the two sub-categories, with LT and without LT.

EScP Instruction with LT

Distribution of LT

As for the implementation of LT in the EScP classroom, the following can be divided into two parts, the target participants and the types of LT. The researchers followed the terms used by Liu et al. (2013) to divide the papers into three main types: specific software, computer-assisted technologies and mobile devices. Figure 5 shows the distribution of LT used in the 15 studies. More than half of the studies (57 %, 4 studies) examined or emphasized the use of computer-assisted technologies, while only 3 studies focused on the use of computers (29 %, 2 studies) and software (11 %, 1 study).

Table 2 The criteria of evaluating the strength of the empirical method designs in the review papers (adapted from Golonka et al. 2014)

Strength	Weak	Moderate	Strong
Definition	Studies with flaws in methodology or methodology not discussed in detail; OR A single well-designed study of any kind with contradictory evidence or with design limitations; OR Expert opinions based on theory or own practice but not empirical data	Two or more experimental, quantitative non-experimental, qualitative, or mixed methods studies with design limitations, such as a low number of participants; OR A single well-designed experimental, quantitative non-experimental, qualitative, or mixed methods study; OR Two or more well-designed experimental, quantitative non-experimental, qualitative, or mixed methods studies with partially contradictory evidence	Three or more well-designed experimental, quantitative non-experimental, qualitative, or mixed methods studies

Table 3 Analysis of studies related to the use of LT in EScP instruction

Study	Participants	Subject	Research aims	Learning focus	Learning technology	Outcome
Meluso et al. (2012)	100 Fifth elementary students in North Carolina	Science in general	To investigate the effects of using game learning on science content learning	Science literacy	Computer	Positive
Wu and Pedersen (2011)	142 Eighth grade African American junior high school students in Texas	Earth science	To examine the effectiveness of a virtual learning environment in science language learning	Science literacy	Computer	Positive
Thang and Bidmeshki (2010)	23 Undergraduates from the Faculty of Science and Technology in University Kebangsaan Malaysia	Science in general	To investigate the perceptions of an online science English course for undergraduate students	Science literacy (reading)	ICT	Positive
Hamilton and Woodward-Kron (2010)	32 International health science students studying at the University of Melbourne	Health science	To examine how ICT help students develop sensitivity toward understanding the target culture	Science literacy (cultural awareness)	ICT	Positive

Table 4 Analysis of studies related to the use of LT in EScP teacher training

Study	Participants	Subject	Research aims	Learning focus	Learning technology	Outcome
Donnelly et al. (2011)	7 Science teachers from Irish postprimary schools	Chemistry	To help develop science teachers skills for integrating ICT into instruction	Service teacher training	ICT	Positive; neutral
Kennedy-Clark (2011)	28 Pre-service teachers from science education course at the University of Sydney in Australia	Science in general	To illustrate the pre-service science teachers' training and attitudes by using software to teach science English instruction	Pre-service teacher training	Software	Positive
Alayyar (2012)	78 Pre-service science teachers	Science in general	To investigate how ICT helps pre-service science teacher training	Pre-service teacher training	ICT	Positive

Distribution of the Target Participants

The researchers further identified participants in those studies. Figure 6 shows the distribution of the target participants. Two out of the 7 articles focused on the tertiary level, and 3 out of the 7 studies aimed at helping both service and pre-service science teachers with EScP instruction.

EScP Instruction Trends Without Integration of Learning Technology

Table 5 indicates the trends in EScP instructions without the integration of LT. There are five studies in 2008–2012 addressing the future implications for EScP teachers such as raising their awareness of the

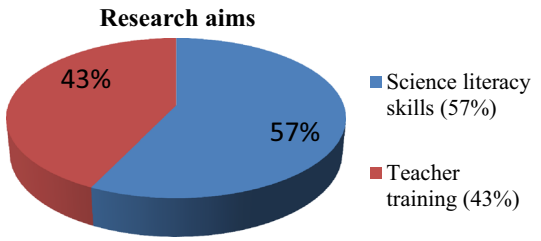

Fig. 4 Distribution of research aims

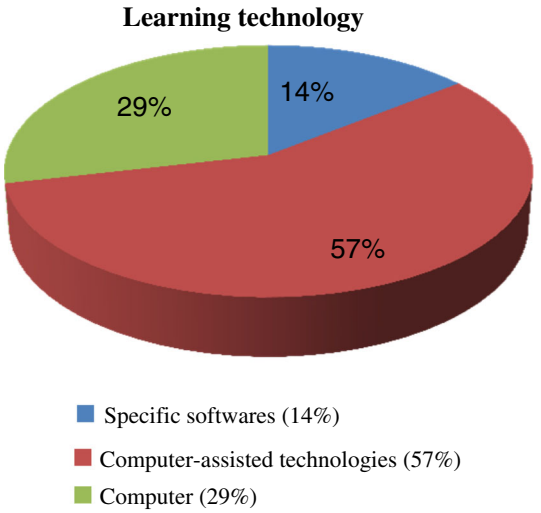

Fig. 5 Distribution of the types of LT

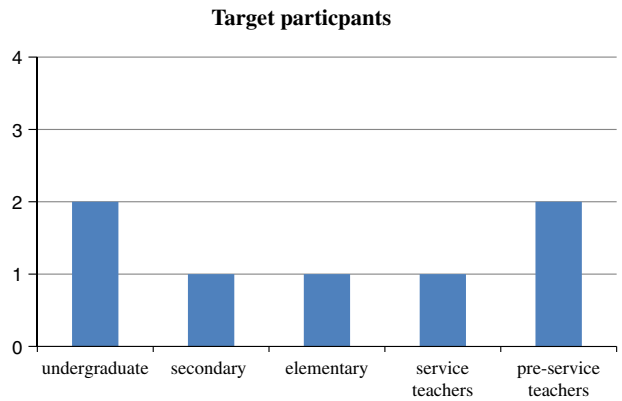

Fig. 6 Distribution of target participants

challenges they may face and the possible new teaching directions.

In the past 5 years, only one study (Cargill et al. 2012) pointed out the challenges facing EScP instruction, which refers to the collaboration between English language teachers and content subject teachers. The other four studies are related to the future of EScP teaching directions, in which two (Chang 2012; Lin and Evans 2012) focused on the influence of discipline-specific differences in English speaking and writing, and two (Soler 2011; Thøgersen and Airey 2011) emphasized the impact of language on the form of instruction. As Thøgersen and Airey (2011) maintain, in English-Mediated Instruction, where English is the main language in an academic context, science instruction courses should be more formal in terms of rhetorical style compared with L1 instruction.

Discussion

The Opportunities and Challenges in the Field of EScP Instruction with LT

The present literature review contributes to our understanding of EScP instruction with LT. According to the present analysis, very few studies focused on how LT enhances overall instruction and few emphasized how LT is implemented in EScP instruction. Also, a related concern is that about half, according to the present findings, put their foci on the part of teacher training, when more attention could be placed on how LT enhances the overall EScP practice in the classroom. As only a limited numbers of studies focused on elementary and high school levels, it could be reasoned that the idea of integrating LT is relatively new, and more professional research and development are needed for this emerging field of study.

Methodological Analysis on the Studies Related to the Use of LT in EScP Instruction

In terms of the methodological analysis of the target papers, which were related to EScP instruction with the use of LT, the following are the findings derived from the target papers (see Table 6).

Research Design Trends and the Analysis of the Effectiveness and Strength of the Empirical Support in EScP Instruction with LT Three out of the four target papers used one type of research method in their studies. The use of one single research method was adopted either quantitatively or qualitatively, which would limit the applications of the results derived from the target papers and which could affect the effectiveness and strength of the empirical support for EScP instruction with the use of LT. For example, in Meluso et al's study (2012), only one single method used to examine how collaborative learning tasks with LT help learners develop scientific literacy by only interviewing participants. Also, Wu and Pedersen (2011) only adopted quantitative way to measure participants' perceptions, which seriously could limit results and applications of the study.

Table 5 Analysis of implications of studies which indicates EScP instruction trends without integration of LT

Implications for EScP instructors' awareness				
Study	Participants/targets for analysis	Methodology	Research aims	Implications for future scientific instruction
Cargill et al. (2012)	Graduate students with scientific expertise in China	Descriptive study	Call for an acute need for collaborations between English teachers and science specialists	To overcome the challenges of *subject and language teachers' collaborations*
Chang (2012)	15 Graduate students from Humanities and Arts, Social Sciences and Education and Physical Sciences and Engineering	Corpus study-(MICASE)-Michigan Corpus of Academic Spoken English	Explore whether disciplinary culture differences would influence Academic Spoken English Instruction	*Disciplinary culture* differences would influence academic instruction
Lin and Evans (2012)	24 Graduate students from a Hong Kong Polytechnic University with 15 fields (particularly in the social sciences and humanities)	Corpus study-analyzing a corpus of journal articles from various disciplines	Present the disciplinary differences in the genre structures of empirical research articles writing, especially for the introductory and concluding parts	*Tailor the materials and academic writing research courses* for research students and early-career academics due to *disciplinary differences*
Soler (2011)	1,140 Titles were analyzed: 570 in English and 570 in Spanish in 1996–2002	Corpus study-analyzing a corpus of titles of scientific journal articles	Compare and contrast the structure of scientific titles in English and Spanish for research papers and review papers on social sciences and biology	How to guide novice scientists to *write research titles* appropriately
Thøgersen and Airey (2011)	Undergraduate students in science courses	Experimental study	Compare and contrast the instruction speaking rate and rhetorical styles in L1 and L2	Teaching the target subject *in English*, teachers should use a higher degree of repetition and *more formal instruction in terms of rhetorical style* compared to L1

Challenges of Using the Methodologies in EScP Instructions with LT Studies In the study of Meluso et al. (2012), challenges toward using the EScP instructions with learning technologies were found. Learners in this study lacked specific knowledge about how to do collaborative learning tasks. Moreover, teachers with limited experience of implementing EScP instructions with LT would also affect the success of using LT to help learners develop science literacy.

Challenges related to hard technology could also be found in the literature such as problems with the learning system design (Wu and Pedersen 2011) and the learners dissatisfaction with the LT (Hamilton and Woodward-Kron 2010; Thang and Bidmeshki 2010).

Methodological Analysis on the Studies Related to the Use of LT in EScP Teacher Training

When it comes to the methodological analysis on the papers related to the use of LT in EScP teacher training, the current study provides the following findings based on four dimensions, namely the overall trends of the research design, the challenges of using the methodologies in the field, implications or suggestions for the future studies and the effectiveness and strength of the empirical support as shown in Table 7.

Research Design Trends in EScP Teacher Training with LT The researchers found that the three studies (Alayyar 2012; Donnelly et al. 2011; Kennedy-Clark 2011) tend to use the mixed-method design, which includes both quantitative and qualitative data. In terms of quantitative data, the researchers in the three studies use experimental and control groups to compare and contrast the teaching and learning outcomes based on the different effectiveness of the learning technologies. As for the qualitative analysis, either open-ended questions in the form of questionnaire or semi-structured interviews were used. According to Oswald and Plonsky (2010), there is a significant need for research design which connect statistical data with practical and reflective perspectives. In terms of the service and pre-service teachers' perspectives on the use of LT for enhancing teaching, more hands-on practice is required to examine its effectiveness; thus, the statistical quantitative research design provides the practical evidence. Nevertheless, qualitative data should also be collected to further understand teachers' experiences of using LT, which could then be used to direct hard technology and soft technology design (Liu 2011).

Challenges of Using the Methodologies in EScP Teacher Training with LT Studies From the scope of soft technologies, four challenges have been identified:

Table 6 Methodological analysis on the studies related to the use of LT in EScP instruction

Study	Research design	Challenges of using the methodologies	Implications or suggestions for future research designs	The effectiveness and strength of the empirical supports
Meluso et al. (2012)	Quantitative/ questionnaire	*(Soft technology)* The collaborative learning tasks were not well organized. Participants in the study lacked specific knowledge and proper strategies about implementing the collaborative learning tasks. *(Hard technology)* The games in the present study were still at the basic level and lacked higher-level assessment	Future scientific instruction could incorporate some games such as CRYSTAL ISLAND, which has been shown to be a powerful learning tool The idea of game-based learning could be further implemented for learners at other levels	Weak
Wu and Pedersen (2011)	Quantitative/ questionnaire	*(Soft technology)* The participants insufficiently prepared for the learning tasks in the virtual learning environment, and the participants did not find the timing of teacher-based metacognitive scaffolding to e useful *(Hard technology)* Computer-based procedural scaffolding was not well developed which might undermine the original idea of using computer-based procedural scaffolding	Future research on whether the scaffolding conditions are influenced by other factors like contexts or participants at different proficiency levels	Weak
Hamilton and Woodward-Kron (2010)	Qualitative/ interview	*(Soft technology)* Aspects such as philosophical approaches, content, and methodology related to ESP instruction were not carefully considered *(Hard technology)* The participants in the study hold a negative view toward the teaching materials, and video clips for some of the intercultural issues	The effectiveness of using video clips to develop learners intercultural competence	Weak
Thang and Bidmeshki (2010)	Mixed-method/ quantitative and qualitative research methods	*(Soft technology)* Cultivating Asian students' autonomy needs different teaching and learning approaches and a more gradual approach *(Hard technology)* Some participants were not satisfied with the online course and still looked forward classroom instruction	Ways in which autonomy is practiced in different forms and in different contexts	Moderate

researchers overlook the importance of interactivity, such as the interactions between learners in embedded instructional activities; whether one single type of LT could overcome all the problems derived from the differences between school cultures and teachers' teaching and learning styles; the lack of instructions on how to manage students' different behavior patterns; and how gender issues and individual differences effect learning outcomes.

Regarding the hard technologies in these studies, there are three challenges: the interfaces of the LTs are not user-friendly; unstable access to learning sources; and instructors not updating the learning resources. These challenges echo what Ogata et al. (2010) mention—when designing the learning system and LT, usefulness, ease of use and providing a user-friendly interface are of vital importance.

Implications for Future Research Designers in EScP Teacher Training Study Area From the results, it is found that the future study designers should be aware of the possible impact of gender differences, provide the LT with sufficient and updated learning resources and activities and

Table 7 Methodological analysis on the studies related to the use of LT in EScP teacher training

Study	Research design	Challenges of using the methodologies	Implications or suggestions for future research designs	The effectiveness and strength of the empirical supports
Donnelly et al. (2011)	Non-experimental study Qualitative/interview (interviews with the science teachers and educational stakeholders)	*(Soft Technology)* Did not consider the interactions of the different types of teachers within the school cultures in terms of ICT integration into instruction *(Hard Technology)* They adapt a one-size-fit-all learning tool—virtual chemistry laboratory, in all the teaching scenarios	Future scientific instruction could make use of ICT integration into subject teaching to facilitate service teachers in written communication with students for concept explanations Examine how different teachers interacted with the ICT to refine future instruction	Weak
Kennedy-Clark (2011)	Experiment study (Experimental group use learning technology; control group use paper-based problem solving materials) Mixed-method design (Quantitative method-questionnaire; Qualitative method-15 question open-ended questionnaire)	*(Soft Technology)* The researcher should provide more scaffolding for the learning activities The researcher should provide online instruction: an online tour The researcher should be aware of the behavior management *(Hard Technology)* Technical limitations: Slow download time for the software The interface is not user-friendly Outdated graphics in the material should be updated Access to the technology is unstable	Enlarge the sample size (There are only 28 participants in the study) ICT should be designed to provide learners with visualization, motivating, interactive, leaner-centered, engaging, risk free, and team work features. To help this enables learners to explain problems and solve them Gender may influence the learners' learning motivation to certain virtual game play and further to affect their attitude to apply the ICT in the future science education Follow-up to see if the pre-service teachers use the ICT in their teaching practicum and the results	Moderate
Alayyar (2012)	Experimental Mixed-method design (Quantitative method-questionnaire; Qualitative method-interviews)	*(Soft Technology)* The researcher does not consider gender differences The researcher does not pin down how the pre-service teachers use the ICT to teach EScP knowledge *(Hard Technology)* Too general: The researcher does not specify the ICT. Different software can lead to different perspectives toward ICT use	Gender may influence the learning outcome and perceptions toward implementing ICT in future teaching Blended learning with ICT tools is more useful than full ICT instruction Holistic assessment of how teachers teach with ICT is needed Develop valid and reliable instruments that measure teachers' Technology Pedagogy Content Knowledge (TPACK) through observable measures ex. by demonstrating their ability to integrate ICT in lesson plans or classroom practice	Moderate

should try to provide the learners with interactive opportunities.

The Effectiveness and Strength of the Empirical Supports in EScP Teacher Training with LT Studies The studies still have some limitations such as not recruiting sufficient participants and not controlling the individual differences such as the learners' gender and teaching backgrounds. Also, the experiments are not tracked by posttests. For the criteria of meta-analyzing the research designs proposed by Golonka et al. (2014), there is some room for the studies to become more solid and valid in terms of the research designs.

Methodological Analysis on the Studies of EScP Instruction Trends Without the Integration of LT

Golonka et al. (2014) classification of the strength of the empirical research effectiveness provides an effective way to analyze a research paper's methodology (see Table 8). Chang's (2012) study of question types is a moderately

Table 8 Methodological analysis on the studies related to EScP instructions without the use of LT

Study	Research design	Challenges of using the methodologies	Implications or suggestions for future research designs	The effectiveness and strength of the empirical supports
Chang (2012)	Corpus study Question analysis using taxonomy of question types. One additional subcategory (classroom management/engagement) was added under the category of audience-oriented questions	Small sample size (15 lectures)	Additional research with a larger sample size is still needed to verify this finding	Moderate
Lin and Evans (2012)	Corpus study Discourse analysis of introduction and conclusion using Yang and Allison's (2003) classification system	Only 20 research articles for each discipline and not all were empirical. Not enough to show variation within each discipline or related discipline. Only uses corpus-based data	Larger sample of empirical research articles across a smaller number of disciplines. Interviews, case studies and surveys to elicit data on use of structural patterns	Moderate
Soler (2011)	Corpus study of titles in English and Spanish. Quantitative (statistical) analysis of title lengths across language and genre (biological sciences and social sciences)	Limited to only biological sciences and social sciences and two languages. More disciplines need to be analyzed. This would show if title is discipline specific or depends on type of research	Larger sample size including a higher number of journals and a more varied selection of disciplines and genres (only looked at research articles and review papers)	Moderate
ThØgersen and Airey (2011)	Case study of a Danish lecturer who lectures in Danish and English. 5 instances of same lecture. Discourse analysis of speaking rate between two languages using Hincks' 2010 method for measuring speaking rate based on mean number of syllables produced between pauses	Limited to one subject and one discipline. No interviews survey or questionnaire: discourse analysis only. No prior corpus-based analysis of differences between Danish and English academic discourse	Questionnaire, survey and interviews needed for students and teacher to show pedagogical, or individual (speaker ability) differences Corpus analysis of academic discourse in both Danish and English needed to show if differences are language specific	Moderate
Cargill et al. (2012)	Quantitative-Questionnaire	Limited to China and EFL contexts. More qualitative methods	Development of collaborative methodologies between science and ELT instructors to help students accomplish academic writing Call for the development of an interdisciplinary research paradigm with increased teacher training	Moderate

strong study due to design limitations—a small sample size of 15 lectures. Three groups are analyzed using an established taxonomy, but the results would be stronger with a more precise statistical analysis. Lin and Evans (2012) corpus analysis of introduction and conclusions in research articles is categorized as a moderately strong research article due to design limitations—the researchers note that it includes non-empirical articles in the results, but the paper is primarily concerned with empirical research articles. Also they acknowledge that the sample size is too small to show a large enough variation. Soler's (2011) corpus analysis of scientific titles in English and Spanish is a moderately strong study because it only compares two language groups and two disciplines within those groups. To be classified as strongly effective research, three or more groups are needed. Thøgersen and Airey (2011) case study is moderately strong because it only has a single subject, but three or more subjects indicate a strongly effective methodology. It also has a design limitation despite the detailed discourse analysis, as the authors note that questionnaires and surveys are also needed to triangulate the data. Finally, Cargill et al. (2012) only used questionnaires, resulting in a moderately strong classification. Although the questionnaire was completed by over

350 graduate students, survey and interview data are needed to strengthen the results.

Indicating the Challenge and Directions for Future EScP Instruction Without LT

Table 4 indicates that research is inclined toward raising teachers' awareness of the challenges and directions for the improvement of future EScP instruction.

From these studies, we gain two important concepts: First, there is an urgent need for collaboration between English language teachers and the content subject instructors. Yet, it seems tough in the present education system despite calls for the field to move in this direction (Cargill et al. 2012). Second, English-Mediated science instruction and EScP material development should be based on scientific disciplinary culture differences since it provides suitable courses and materials for the target students (Chang 2012; Lin and Evans 2012). As seen in the methodology column in Table 5, students' language needs are often met via corpus studies, which contain the target learner's authentic language needs—the standardized, scientific language used by the international scientific community (Chang 2012; Lin and Evans 2012; Soler 2011). Teachers without a strong scientific research background, who could be asked to teach ESP and EScP courses due to their language instruction expertise (Butler 2005), can also consult the relevant corpora to determine the exact authentic language needs within a scientific field.

Conclusion

The current paper systematically synthesized and categorized the issues and factors of applying LT into EScP instructions and contributed to the field's understanding of the various types of teaching and learning approaches, methods, available resources, learning outcomes, instruction challenges and research trends. The literature review proposed that a synthesis of Scientific Literacy Instruction (SLI) with English language instruction is needed to provide EScP students with the necessary language, discourse and critical thinking skills for scientific research. For future studies, since the numbers of reviews compared with other fields were still limited, more papers on how LT can be applied into EScP instruction are called for. Additionally, for EScP teachers and instructional designers, applying LT into the classroom is a relatively novel idea so Action Research is needed to guide instructors on how to implement technology in addition to highlighting areas that require further research.

To sum up, based on the studies related to EScP published in 2008–2012, it is suggested that science instructors should turn teacher-centered courses into student-centered instruction by using data-driven approaches such as the corpus studies by Chang (2012), Lin and Evans (2012) and Soler (2011). Critical reviews on global forums and asynchronous online discussions (AOD) can also shift the paradigm to student-centered instruction (Loncar et al. 2014). There is also a real need for newly designed EScP materials and curriculum and a need to integrate CALL approaches (such as linguistic gaming, textual chats and video-conferencing collaborations with scientific literacy developments) to the course so that the EScP learners can achieve better comprehension of scientific texts. More importantly, EScP learners and instructors need to be aware of how LT cannot only enhance the learning of new materials, but also help develop the critical and higher-level thinking skills needed in modern education and workplaces worldwide. To promote effective and efficient scientific literacy, as Loncar et al. (2014) point out, digital natives need more technology-driven, autonomous, self-oriented strategies and research to meet the current needs of globalization, collaboration and competiveness. By these means, students can enhance their English language proficiency and content learning efficiency while still staying immersed in the science-based learning process.

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