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SLA as an interdiscipline: A bibliometric study

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Abstract

Nowadays, research in second language acquisition (SLA) is becoming increasingly interdisciplinary while many technical frontiers and research hotspots have emerged. Many studies focus on interdisciplinary topics, but few in-depth studies have been conducted on interdisciplinarity. This study examined the interdisciplinarity of SLA and the interdisciplinary development process using a bibliometrics approach. The study has found that the SLA discipline has played roles as both the provider and recipient of knowledge in the development of interdisciplines. In the first case, SLA theories and methods flow into the research areas of *life sciences* and *technology* to form interdisciplinary studies with brain research, neurology, cognition, computer technology, and engineering, making SLA a provider of knowledge In the second case, SLA research receives knowledge from areas of arts and humanities and social sciences as well as from interdisciplinary studies within its own discipline, making SLA a receiver of knowledge. The new insights into the interdisciplinarity of SLA provided in this study are helpful for our deeper understanding of the interdisciplinary nature of the SLA discipline.

Keywords: bibliometrics; interdiscipline; interdisciplinary development; knowledge flow; second language acquisition

1. Introduction

The interdisciplinary development and evolution of second language acquisition (SLA) with adjacent fields has been a core research focus (Ortega, 2013; Tarone,

2015). Past studies have demonstrated the importance and complexity of further understanding of SLA interdisciplinarity. For example, Atkinson (2011) brought together six new research approaches in SLA and claimed that research in other disciplines was isolated. Klein (1998) observed that SLA researchers liked to invite people from other language disciplines but researchers in other disciplines did not do the same. However, despite existing discussions on the interdisciplinarity of SLA (Kramsch, 2003; Liddicoat, 2010; Neupane, 2019), many unresolved issues and challenges remain. Prior studies on SLA interdisciplinarity have been mainly qualitative and based on experts' experiences (Kramsch, 2003; Liddicoat, 2010; Ortega, 2013). Some studies employed bibliometric analysis to examine the development of SLA (Chen, 2018; Zhang, 2019) and its connections to other fields (Zhang & Sun, 2017). However, these bibliometric studies relied on basic statistical indicators and did not specifically focus on measuring interdisciplinary interactions.

In light of these gaps, this study aims to investigate the interdisciplinary nature of SLA using a bibliometric approach. We hope to gain a better understanding of the interactions between SLA and related research fields during SLA's development process through quantitative analysis of bibliometric data, and provide new insights into the future interdisciplinary development trends of SLA. Furthermore, this study utilizes an advanced bibliometric approach involving three-field plots and thematic mapping to quantitatively analyze the bidirectional knowledge flows between SLA and other disciplines. Compared to past research, this method allows for a more granular and empirical examination of how SLA has developed interdisciplinary relations by tracing flows of cited references. The findings will provide new, data-driven insights into the evolution of SLA as an interdiscipline. The specific research questions addressed in this study are:

1. How has SLA research crossed over into other academic disciplines and formed interdisciplinary research areas or sub-disciplines in those disciplines over the past 20 years?
2. How has research of other academic disciplines crossed over into the SLA discipline and formed new interdisciplinary research areas or sub-disciplines with existing SLA research during the same period?

This study provides much needed empirical evidence on the evolution of SLA as an interdiscipline using bibliometric analysis. The findings will contribute new knowledge about the interdisciplinary nature of SLA and its connections to other fields, and help inform future research and theoretical development in the field.

2. Literature review

2.1. Disciplinarity of SLA research

In the 1970s, studies of linguistics, psychology, and education merged, and SLA emerged as a new interdisciplinary field (Kramsch, 2003). By the early 1990s, at least 40 theoretical models were established in the SLA research field (Ellis, 1994; Gass et al., 2013; Larsen-Freeman & Long, 1991; VanPatten, 1999). SLA research has a close relationship with second language (L2) teaching and covers many fields directly related to foreign language education, child language research, language research, sociocultural studies, and psycholinguistics (Dixon et al., 2012). The field of SLA research has been viewed as a branch of applied linguistics (Kramsch, 1993; McCarthy, 2001), educational linguistics (Cook, 1985; Ellis, 1994; Larsen-Freeman & Long, 1991; VanPatten, 1999), cognitive science (Dakowska, 2013; Richards & Schmidt, 2013), or an independent discipline (Gass, 1993; Klein, 1998; Neupane, 2019), but a consensus has yet to be reached on what subjects should be included in SLA (Holbrook, 2013).

The interdisciplinarity of SLA research has received attention from scholars from time to time (Klein, 1998; Kramsch, 2003; Leung et al., 2019; Neupane, 2019; Ortega, 2013, 2018; Tarone, 2015). However, the majority of the studies were the researchers' views of the interdisciplinarity of SLA based on personal experience. For example, Ortega (2013) reviewed the 40-year history of SLA and claimed that SLA research was theoretically more diverse and interdisciplinary than ever before in terms of the number of empirical studies and the sophistication of research methods. Gass (1993) summarized the interdisciplinary research in SLA based on the review of journals in the psychology, education, and health category, the main publication sources of SLA research. She observed that SLA research relied heavily on theoretical issues in other fields, but few discoveries or theoretical insights had contributed to the development of other fields. In her examination of SLA research, Klein (1998) pointed out that SLA researchers tended to invite people from other language disciplines to participate in meetings, but researchers of other disciplines did not do the same. SLA researchers seem to be "bottom dwellers in the field of language sciences" (Klein, 1998, p. 530). Even after years of development of SLA, Dakowska (2013) found that the direction of influence between SLA and research in other disciplines has been almost exclusively from the latter to the former.

2.2. Perspectives on SLA's interdisciplinary nature

Some researchers believed that the interdisciplinary nature of SLA is not obvious and should be strengthened. Atkinson (2011) brought together six new research

approaches in SLA. He claimed that, with a few exceptions, the research in other disciplines within the SLA discipline was isolated. Liddicoat (2010) even suggested that interdisciplinarity barely existed in SLA research. He defined interdisciplinary studies as using knowledge or methods from multiple disciplines by a single researcher instead of using knowledge or methods from different disciplines to solve problems by different researchers; the latter could only be regarded as multidisciplinarity. Therefore, some researchers held the view that it was more suitable to adopt a multidisciplinary framework when doing SLA research. For example, Atkinson et al. (2016) proposed to divide SLA into three levels: micro, meso, and macro, with each level containing different disciplines to constitute an interdisciplinary research framework. Hall (2019) put forward an interactive linguistics-based research framework based on conversation analysis. Although these proposed frameworks were considered to be able to greatly improve SLA research, they were just some proposals yet to be verified empirically.

According to the views of some researchers, the crossover of SLA research to other disciplines is common yet often it happens to a limited extent. For example, Kramsch (2003) summarized the main work of SLA interdisciplinary research as pursuing psychological validity, educational reliability, pedagogical effectiveness, and identifying social and institutional opportunities and constraints. She suggested that, from the perspective of the theory and practice of language learning, research in SLA or even in applied linguistics was not very interdisciplinary, and rarely occupied a place in the traditional academic system. Because both SLA and applied linguistics were considered to focus on teaching, not on research, researchers in established disciplines such as linguistics, literature, sociology, and psychology often question the validity of SLA as a discipline (Kramsch, 2003).

More recent years have seen a few bibliometric studies on SLA (e.g., Chen, 2016, 2018; Zhang, 2019; Zhang & Sun, 2017) which have provided overviews of the development of SLA as a discipline in which important research themes and potential development trends were identified and visually presented together with information on prominent works and authors from both inside or outside of the discipline. For example, Chen (2018) claimed that SLA was a specific and narrow research field in the broader disciplines of linguistics and pedagogy, and the lack of pivotal references in SLA made it difficult to integrate the SLA discipline with other fields. She further claimed that although SLA research had a greater "demand" for other disciplines, over the years, the impact of SLA on other disciplines had not increased much.

Based on a review of existing literature, it appears that the interdisciplinary research in SLA has made considerable progress, but there remains a lack of a clearly defined research framework in the study of SLA interdisciplinarity. In addition, although previous studies have shed light on SLA's development and its interactions with other disciplines, there is no quantitative research on its interdisciplinarity. As a result,

we do not have a clear understanding of the intellectual flow when SLA research forms interdisciplinary interactions with other disciplines and we do not know to which extent SLA and other disciplines need each other. Therefore, this study is focused on the interdisciplinary nature of SLA, and unlike previous studies, quantitative methods are used to measure the interactions between SLA and other disciplines.

2.3. Bibliometric studies: An overview

In the previous section, bibliometric studies in SLA were briefly mentioned. Bibliometric study is an approach in sociological analysis of science, based on the pioneering work of Garfield et al. (1975), which involves transforming raw bibliographic data into information useful to scientists and librarians. Citation analysis, co-citation analysis, citation networks, informetric laws, and author productivity analysis are some of the common tools used in bibliometric studies (Todeschini & Baccini, 2016). By analyzing the links between references in research publications, a complete network path can be provided for a comprehensive examination of the subject area. The computer revolution has accelerated the development of bibliometric studies.

Small (1973, 1999) argues that the interdisciplinarity of a discipline can also be measured by examining the references of disciplinary papers, that is, how the discipline integrates knowledge from other disciplines. Bibliometric studies also provide some relatively new methods for studying interdisciplinarity. A simple approach is to quantify the knowledge transmitted from other disciplines to the interdisciplinary field by counting the number of references from different disciplines used in a research paper, or the frequency of citations from other disciplines, a method used by many researchers (Porter & Chubin, 1985; Porter et al., 2007; Qin et al., 1997). Rafols and Meyer (2010) even proposed metrics such as Gini coefficient and Rao-Stirling to measure interdisciplinarity, and the method is still used in many studies today (Karunan et al., 2017). However, it only looks at the knowledge relationships between interdisciplinary fields and their source disciplines from a broad level rather than at a more granular level of subtlety (Xu et al., 2016).

2.4. Methods in bibliometric studies

Some studies have analyzed interdisciplinarity by looking at the percentage of papers published by authors from disciplines other than their own (Pierce, 1999; Rinia et al., 2002), or the collaborative relationships between scholars from different disciplines (Qiu, 1992). For example, Pierce (1999) analyzed papers published in four core journals in political science and sociology between 1971 and 1990, and found that 199

of them had first authors from other disciplines and only one-sixth of the papers had co-authors from the journal's discipline. Thus, Pierce (1999) argued that the boundaries of disciplines were not as strictly limited as the literature claimed. Schummer (2004) analyzed the co-authors of over 600 papers published in nanoscience and nanotechnology in 2002 and 2003. Other studies went further in measuring the literature of research groups and institutions (Bailón-Moreno et al., 2006; van Raan, 2000; van Raan & van Leeuwen, 2002).

There are some studies that take a cross-disciplinary approach to the broad level of the whole science. For example, Rinia et al. (2002) provided insights into the intellectual body of science by analyzing interdisciplinary citations in journal articles to consider the exchange of knowledge between disciplines globally, based on the output of world publications in 1999. In another example, van Leeuwen and Tijssen (2000) analyzed citations between journals in 119 disciplines to provide a broad overview of the multidisciplinary nature of research activity at the international level and across a wide range of disciplines. These findings provide preliminary evidence for significant differences between disciplines in terms of interdisciplinary orientation.

There are also quantitative studies that look at interdisciplinarity by distilling the knowledge structures of interdisciplinary fields (Lee & Jeong, 2008; Liu, Hu, & Wang, 2012; Piepenbrink & Nurmammadov, 2015). Nichols (2014) proposed a Stirlin indicator based on research themes to measure the interdisciplinarity of NSF proposals. Similarly, Xu et al. (2016) studied the co-occurrence of terminology in the fields of information science and librarianship. They identified and analyzed the involved disciplines and their specific involved themes, and proposed a metric to measure the interdisciplinarity with terminology.

Some other researchers, when analyzing interdisciplinarity, have first strictly divided the research field into disciplines and then examined the relationship between citations using the bibliometric approach. For example, Ba et al. (2019) proposed a new hierarchical structure to reconstruct the fields of medical informatics and computer science, and then analyzed the knowledge transfer and knowledge integration between different disciplines to finally describe the interdisciplinarity of these two fields. Similarly, because of the wide range of nano-research topics, Stopar et al. (2016) first grouped the Web of Science (WoS) subject categories (SCs) of relevant nano-research into four categories, and then analyzed the interdisciplinarity and dispersion of nano-research through the citation relationships of these categories. Similar approaches have been adopted by Katz and Hicks (1995), Leydesdorff and Cozzens (1993), Morillo et al. (2003), Moya-Anegón et al. (2004), van Raan (2000), and others, who have used SCs to examine various aspects of interdisciplinary knowledge exchange.

Bibliometric analysis provides a new approach to investigating interdisciplinary knowledge integration. Previous SLA studies have been conducted mainly by

experts based on experience. Due to the influence of the investigators' own research background and expertise, such studies are mainly qualitative in nature and tend to focus only on a particular research direction in SLA. As Plonsky (2015) has rightly pointed out, our research questions are being constrained by our knowledge of statistical tools. Although a few studies on SLA interdisciplinarity are supported by data, the total amount of literature analyzed is still relatively limited. There is a need to employ quantitative methods in SLA interdisciplinary studies, as they may eliminate the influence of vocal critics and increase the objectivity, transparency, and replicability of results (Gass et al., 2013). Bibliometric studies have emerged as an effective quantitative approach in addressing interdisciplinary issues.

2.5. Applicability of bibliometric methods to SLA

Among the above-mentioned bibliometric methods, the methods of calculating citation frequency and analyzing author collaboration can only offer a cursory description of interdisciplinarity (Xu et al., 2016). The bibliometric approach of looking at interdisciplinarity by distilling the knowledge structure of interdisciplinary fields is suitable for relatively large fields with a large number of journals, while the SLA discipline that is of interest in this study is not so large, with only a few major journals, the top 13 of which publish 50% of the papers (Chen, 2016).

Therefore, this study will restructure and define the domain of SLA and its related disciplines based on bibliometric information, tracing the origin of the bibliometric information to investigate to what extent and how SLA interacts with other disciplinary fields. The approach to the measurement of interdisciplinarity adopted by this study looks at the knowledge integration in terms of the direction of citation flows. Its approach to restructuring research domains has been adopted by many studies (Ba et al., 2019; Morillo et al., 2003; Stopar et al., 2016), but has not been used in interdisciplinary studies of SLA, and the use of this method is believed to yield meaningful results.

3. Research methods

3.1 Data collection

In this study, the Web of Science database from Clarivate was used to collect bibliometric data. Taking into account the word searches used in previous bibliometric studies on SLA (Chen, 2018; Dixon et al., 2012), the searched words used in this study were: TS=((„second language" OR "foreign language") AND (acquisition OR learn* OR teach* OR education)) AND Language: (English) AND Document Type: (Article).

The timespan was set to 2000-2020. The search yielded a total of 17,072 records. Since topic search (TS) was used, our search returned papers whose title, abstract, or keywords matched the search string (Clarivate, 2021). The information contained in these three places all contributed to the retrieval of a particular paper. The search did not look for papers by their reference list; articles that cited a particular paper (e.g., a SLA paper) would be captured only when their title, keywords, or abstract content matched the search string and their publishing date fell between 2000 and 2020.

Our TS search combined Boolean operators to achieve the best search result. A SLA paper might be missed out due to a lack of a particular search word in our query but it would still be captured by another as long as one of the search words appeared in the title, abstract, and keywords (Clarivate, 2021). We refined the search by English works because English is the dominant language in academic publications today and the majority of quality studies find their way into English international journals, especially those indexed by Clarivate and Scopus. Even though some non-English papers might be excluded, they would still be included in our datasets through citing of or being cited by the other papers we retrieved. Furthermore, most bibliometric research tools do not support multilingual data analysis, and the author of this paper was not able to master languages other than English and her native language to conduct analysis of non-English works. According to the updated information from the WoS website (Web of Science, 2021), the WoS classified subject categories into 254 categories, which were grouped into five broad research areas, that is, *arts and humanities*, *life sciences*, *physical sciences*, *social sciences*, and *technology*. It was assumed that the captured papers published in journals of the SLA discipline were related to other disciplines in addition to their inherent relevance to the SLA discipline (the interdisciplinarity of the SLA discipline), but also that the captured papers published in journals representing other disciplines were primarily relevant to their own field of study but also to SLA.

Any WoS-indexed journal is assigned to a SC, but can also be assigned to multiple categories, which is known as multiple assignment (Morillo et al., 2001). Most journals are assigned to one SC, and some journals are linked to two or more SCs (Hicks & Katz, 1996; Leydesdorff & Cozzens, 1993). Although there are some criticisms of WoS's SC being imperfect and too old (developed 40 years ago), its classification being done manually, and its algorithm not being made public (Boyack et al., 2005; Loet Leydesdorff, 2006; Leydesdorff & Cozzens, 1993), the majority of researchers use search results from WoS database as their data source when carrying out bibliometric studies (Waltman & van Eck, 2012). In this study, WoS was used because it is a relatively good-quality database and is widely used by bibliometric studies.

3.2. Identification of research areas

Since the WoS SCs do not directly correspond to any one discipline and the search results are not automatically categorized into the five upper-level research areas mentioned above, this study relies on manual categorization to classify the search results into the five larger research areas according to the WoS research areas (categories/classification) guidelines (Web of Science, 2021) using the *refine* and *exclude* functions provided by WoS, respectively.

Currently, the subject category in the WoS database also includes interdisciplinary and multidisciplinary categories, journals which may play an important role in knowledge transfer between disciplines. However, as pointed out by Xu et al. (2016), in the analysis of interdisciplinary disciplines, it is not a good practice to analyze interdisciplinary journals alone. Therefore, the current study chose not to rely on interdisciplinary and multidisciplinary categories alone as the data source.

3.3. Datasets of inbound and outbound SLA citation flows

In bibliometric studies, measuring interdisciplinarity is invariably operated on citation relationships. This study calculated the two-way intellectual flows between the SLA discipline and disciplines in other research fields, that is, not only research in various disciplines that had been cited by research in the SLA discipline, but also SLA research that had been cited by research in other disciplines.

As Rinia et al. (2001) pointed out, many subject categories in the ISI (predecessor of WoS) were too closely related, and they did not correspond to academic disciplines. I thus only analyzed the interdisciplinary relationship between SLA disciplines and each broad academic area rather than each discipline. Among the five broad academic areas of WoS, the *arts and humanities* and *social sciences* areas are closely related to SLA through the *language linguistics* subject category under the *arts and humanities* area and the *linguistics* subject category under the *social sciences* area. *Language linguistics* under the *arts and humanities* academic area and *linguistics* under the *social sciences* academic area are the subject categories assigned to the majority of our search records. Since these two academic areas were closely connected with SLA, the interdisciplinary relationships between SLA and both of them were referred to in this study as SLA research. The interdisciplinary relationships between SLA and any of the other three broad academic areas were referred to as non-SLA interdisciplinarity.

In this study, the keyword search results were differentiated into five academic areas of WoS, and further used the functions of *refine* or *exclude* provided by WoS to obtain two types of datasets: bibliometric data of SLA research cited

by publications of other disciplines (outbound dataset) and bibliometric data of research in other disciplines cited by research in SLA (inbound dataset). It is possible for a paper to be classified into multiple categories in the WoS classification system. If the multiple categories belonged to the same academic area, the duplicates were removed by Bibliomatrix's own cleaning function, which ensured that in each inbound and outbound academic area dataset, papers were all unique records without duplicates. The following specific steps were taken to obtain the datasets.

1. Outbound bibliometric datasets from the SLA discipline to other disciplines. We first refined the search result with the subject categories of each academic area. For example, we refined the search result as shown in Figure 1, to include the records assigned to the subject categories (ticked in Figure 1) that represented the academic area of *arts and humanities* (Web of Science, 2021). The records obtained from this kind of refined search were considered to contain SLA references and, by tracing the citations of the SLA references in different academic areas, we identified which SLA research had been cited in non-SLA research, and thus evaluated to what extent and how SLA had developed in other disciplines.

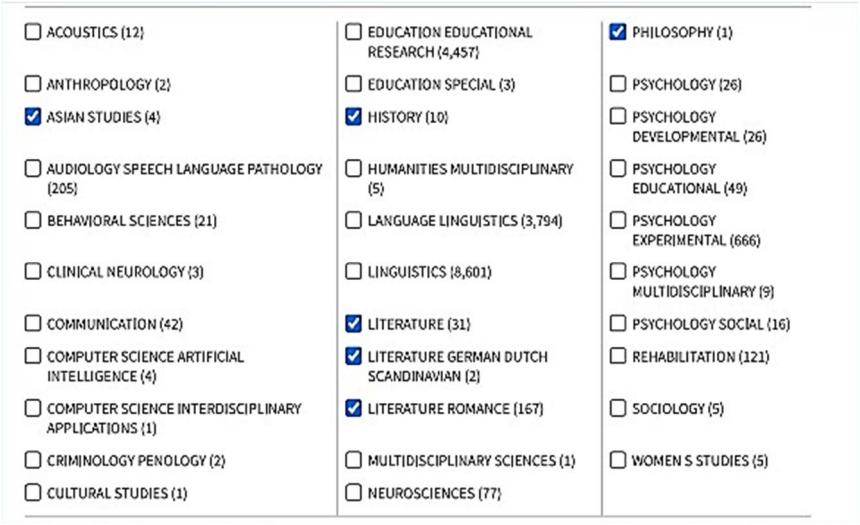


Figure 1 Refined search results for *arts and humanities*

2. Inbound bibliometric datasets from other disciplines to SLA discipline. I used the *exclude* function provided by WoS for managing subject categories to exclude two categories namely, *linguistics* and *language linguistics*, which represented SLA studies in the 5 academic areas. I then obtained records

(research publications) which were considered to be related to SLA (because they were obtained by using SLA search terms) but also contained many non-SLA theories and models from non-SLA disciplines. For convenience, I first excluded from my original 17,027 records the records assigned to *linguistics* and *language linguistics* categories to obtain 7,737 records, and then differentiated the 7,737 records into datasets by the five academic areas of WoS. For example, after excluding *linguistics* and *language linguistics* categories, the inbound dataset of the academic area of *arts and humanities* was obtained by ticking the subject categories shown in Figure 2.

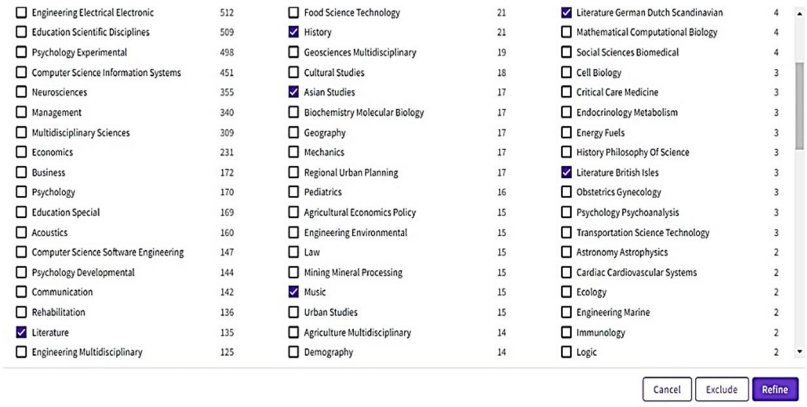


Figure 2 Inbound bibliometric dataset of *arts and humanities*

3.4. Research instruments and analysis

We chose Bibliometrix (Aria & Cuccurullo, 2017), a free R-based software for bibliometric studies, as our research tool primarily because it provided the so-called Three-Field Plots function that could put the relationships of three fields (references, cited sources,[1] and keywords plus[2] in our case) on a Sankey diagram. With this tool, we tracked how bibliometric information of SLA research "flowed" from SLA to other disciplines and vice versa, as well as the publication sources through which the information passed. We set the left field to *references*, the middle field to *cited source*, and the right field to *keywords plus* when using three-field plots. As shown in Figure 3, the parameters were set to 20 when we processed the outbound dataset of the academic area of *arts and humanities*.

[1] Cited sources refer to the original publication sources from which research articles have drawn their references.

[2] A keyword classification system provided by WoS to automatically generates keywords from the title of cited articles.

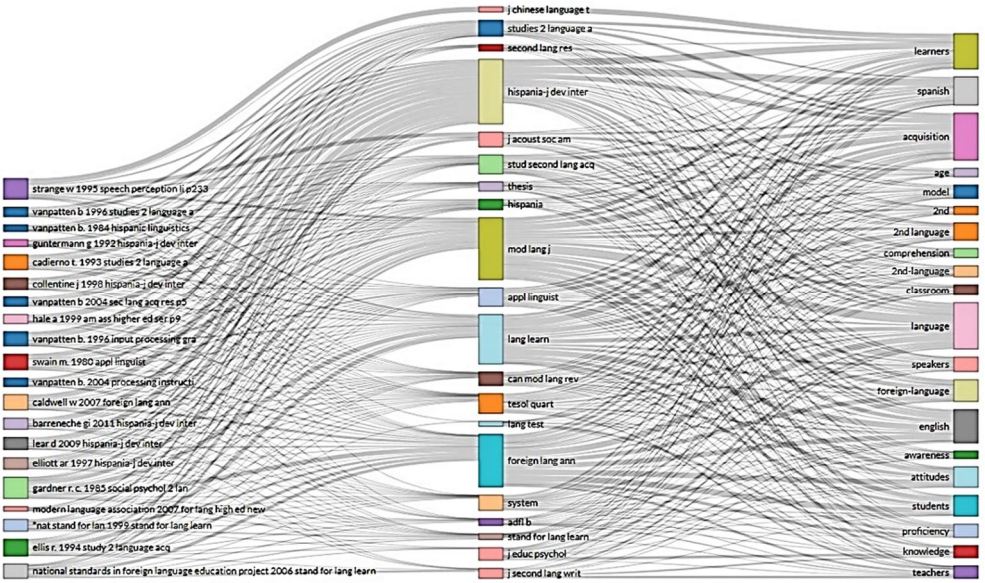


Figure 3 Settings for *three-field plots* (in Figure 3 and similar diagrams that follow, the shaded areas reflect the volume of information flow: denser shading signifies greater flow, highlighting key interdisciplinary interactions and prominent research themes in SLA)

The relevant elements under references, cited source, and keyword plus in the three-field plots were represented with rectangles of different colors. The height of a rectangle was proportional to the sum of relations between the element represented by the rectangle and other elements. The more relations an element had, the higher the rectangle representing it was. For example, the appearance of "gardner r.c. 1985 social psychol 2 lan" in the left column meant that it was a top 20 SLA literature that had been cited most frequently by studies included in our dataset under a particular WoS category (*arts and humanities* in this case). In the middle of the plot are the most frequently published journals in *arts and humanities*, one of the five broad academic areas. The thin line on the right of this paper connects it to a series of journals such as "foreign lang ann" [Foreign Language Annals], "lang learn" [Language Learning], and "mod lang j" [Modern Language Journal], meaning that it is cited in papers of these journals. Gardner's (1985) psychological theory on attitude and motivation flowed into SLA research and became well-established in SLA pedagogy through a great number of works (Csizér & Dörnyei, 2005; Pyun, 2013; Winke, 2013) published in those SLA journals.

Setting a threshold was subjective; some real interdisciplinary SLA studies could be counted as non-interdisciplinary ones if we set the threshold too high. However, if the threshold was set too low and studies with one or two citations

would be counted as interdisciplinary research, then there would be a risk of non-interdisciplinary studies being treated as interdisciplinary ones.

In addition, the Bibliometrix software package used in this study generated thematic maps using co-keywords. It created thematic maps based on the approach of co-word network analysis and clustering (Cobo et al., 2011). Research themes fell into a flat map, where quadrants one to four could distinguish them into important and well-developed motor themes (quadrant one), highly developed and isolated themes (quadrant two), emerging or declining themes (quadrant three), and basic and transversal themes (quadrant four). We set the number of keywords to 1/3 of the total keywords in the dataset.

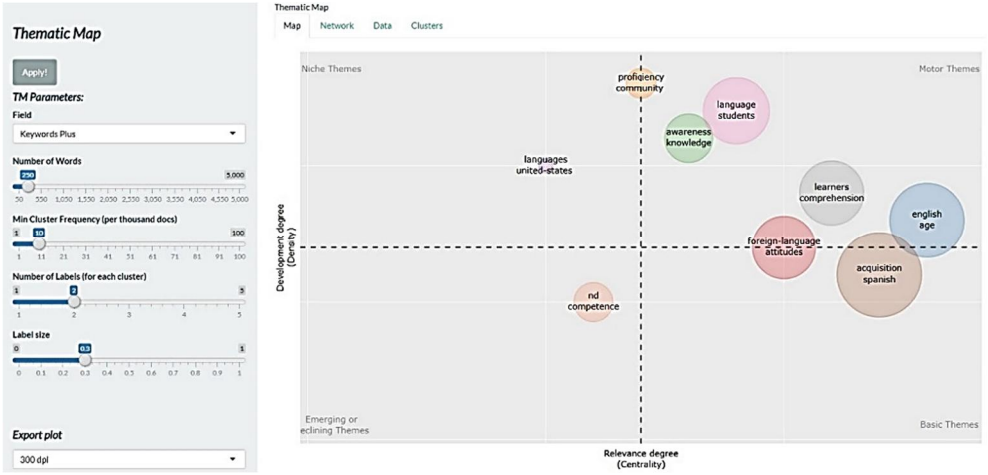


Figure 4 Settings for thematic mapping

For example, the outbound dataset of *arts and humanities* had a total of 750 keywords generated from 215 documents, and we set 250 keywords for the thematic mapping analysis of this dataset as shown in Figure 4. The setting for *min cluster frequency* was subject to manual adjustments, and the most meaningful thematic fields were produced when it was set to 10 in the analysis. The map showed that there were many research themes (represented by abbreviated names in the circles) in the first quadrant, indicating that SLA research in *arts and humanities* was well-developed. The circle "languages/united states" in the 2nd quadrant indicated that the theme of SLA teaching was still attracting much research attention, but it was mainly focused on teaching in the US. The circle "nd competence" in the 3rd quadrant indicated that the research on 2nd language competence was a declining research area since it had been around for many years and could not be an emerging one. The circle "acquisition spanish" in the 4th quadrant indicated that Spanish acquisition remained a long-lasting research theme in *arts and humanities*.

In sum, we analyzed not only the papers retrieved but also their references. Actually, the analysis of their references played a major role. Our three-field plots and thematic mapping were aimed to analyze the references. Although the papers from other disciplines were related to SLA, their references were more likely to be related to their disciplines (otherwise they would not be published in the journals representing that discipline) than to SLA. From analyzing the SLA works cited in their references, we tried to detect whether SLA crossed over into these disciplines.

Take the following A, B, and C articles for example. Article A is an SLA paper. It cited 148 references (including article B in the field of neuroscience) and it has been cited 165 times by other sources (including article C in the field of *ethics*).

- A: Lantolf, J. P. (2006). Sociocultural theory and L2: State of the art. *Studies in second language acquisition*, *28*(1), 67-109.
- B: Heiser, M., Iacoboni, M., Maeda, F., Marcus, J., & Mazziotta, J. C. (2003). The essential role of Broca's area in imitation. *European Journal of Neuroscience*, *17*(5), 1123-1128.
- C: Chien, S. C. (2017). Taiwanese college students' perceptions of plagiarism: Cultural and educational considerations. *Ethics & Behavior, 27*(2), 118-139.

In this example, being an SLA-related study, A will definitely be captured. Because A cites B, B will appear in A's references and will therefore be retrieved in the dataset. As for whether B will be considered to have an influence on SLA, it depends on whether the number of times it is cited by other SLA papers meets the threshold of 20 (the 20 most cited documents) set in our three-field plots. Similarly, for B's keywords to appear in the thematic map, they need to be among the top 1/3 of the keywords most frequently used by all authors. Whether C will appear in our dataset depends on whether its title, keywords, or abstract is relevant to SLA. It is assumed that, for a study published in a non-SLA journal to be considered as an interdisciplinary SLA research, its author(s) would at least somehow acknowledge its SLA relevance in the title, keywords, or abstract in addition to just citing a few SLA studies.

4. Results

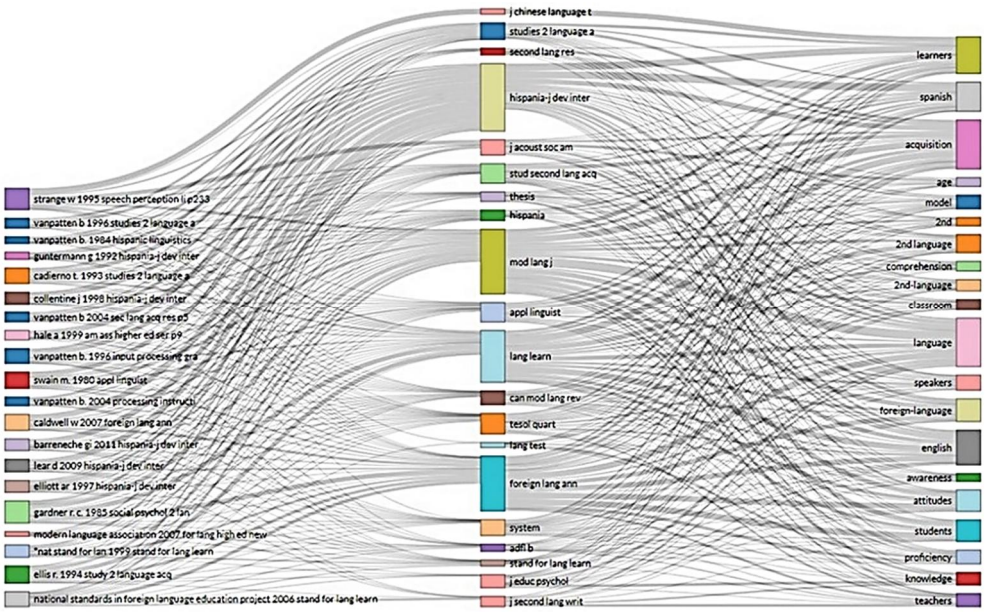
To answer the question of how SLA research crossed over into other academic disciplines and formed interdisciplinary research areas, each outbound dataset, whose main information is presented in Table 1, was analyzed and the results of the analyses together with three-field plots, thematic maps, and statistics are presented in the following parts.

Table 1 Main information on outbound datasets

	Arts and humanities	Life sciences	Physical sciences	Social sciences	Technology
Sources (journals, books, etc.)	15	19	0	65	4
Documents (research papers or works)	215	273	0	4959	17
References	6847	11146	0	123198	965
Keywords plus (ID)	270	845	0	4827	88

4.1. *Arts and humanities* (refined by *language linguistics* and *linguistics* categories)

Table 1 shows that the dataset of *arts and humanities* contains a total of 215 documents with 6,847 references, 15 cited sources, and 270 keywords. Figure 5 and Table 2 show the top 20 most cited references, the keywords generated from the 215 documents, and the most cited publication sources for the 6847 references, and the dense lines indicate that research in *arts and humanities* is closely associated with SLA. The right panel of Figure 5 shows that most of the research themes are in the first quadrant, indicating that SLA research in *arts and humanities* is well-developed.



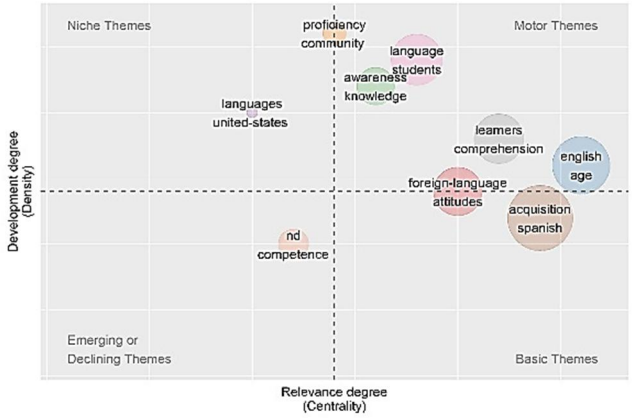


Figure 5 Intellectual flows from SLA to other disciplines of *arts and humanities*

Table 2 Interdisciplinary SLA studies in *arts and humanities*

Most local cited references	Citations	Cited sources	Clusters and keywords plus
Vanpatten b., 1996, input processing gra	10	Mod lang j	Clusters
Nat stand for lan, 1999, stand for lang learn	8	Hispania-j dev inter	foreign-language;
Cadierno t., 1993, studies 2 language a,	8	Foreign lang ann	English;
Caldwell w, 2007, foreign lang ann, v40,	8	Lang learn	awareness;
Ellis r., 1994, study 2 language acq	8	Studies 2 language	languages;
Gardner R. C., 1985, social psychol 2 lan	8	Appl linguist	proficiency;
Swain m., 1980, appl linguist, v1, p1,	8	Tesol quart	acquisition;
Modern lang ass, 2007, for lang high edu	7	System	language;
Strange w, 1995, speech perception li,	7	Hispania	learners;
Barreneche gi, 2011, hispania-j dev inter,	6	Stud second lang acq	2nd
Collentine j, 1998, hispania-j dev inter,	6	Second lang res	Keywords plus:
Elliott ar, 1997, hispania-j dev inter, v80,	6	J second lang writ	acquisition, language, English,
Hale a, 1999, am ass higher ed ser le , p9	6	Adfl bulletin	Spanish, learners, foreign-lan-
Lear d, 2009, hispania-j dev inter, v92,	6	Thesis	guage, students, attitudes,
Nat stand in foreign lang educ project,	6	J acoust soc am	model, proficiency, 2nd, 2nd lan-
2006, stand for lang learn		Can mod lang rev	guage, 2nd language, awareness,
Vanpatten b, 1996, studies 2 language a,	6	J educ psychol	comprehension, knowledge,
Vanpatten b, 2004, sec lang acq res, p5	6	Stand for lang learn	speakers, teachers, age, class-
Vanpatten b., 1984, hispanic linguistics,	6	J Chinese language	room
Vanpatten b., 2004, processing instructi	6	Lang test	
Bachman l. F., 1996, language testing pra	5		

4.2. *Life sciences* (refined by *Language linguistics* and *linguistics* categories)

Table 1 shows that the data set of *life sciences* contains a total of 273 documents, with 11,146 references cited, 19 published sources of these 273 documents, and 845 keywords. We can see the strong interaction between SLA and *life sciences* in the left panel of Figure 6, and there are nine major research themes shown in the right panel of Figure 6. In addition to traditional SLA research themes such

as language teaching/second language, there are also non-traditional SLA issues, namely, *working memory*, *memory*, *brain*, and *costs*. These topics are distributed in four quadrants. The *children (skill)*, *brain (representation)*, and *speech-perception (Spanish)* are the three topics that have developed steadily and well. The research on *costs (executive control)*, *memory (word recognition)*, and *working memory (comprehension)* has been highly developed. The areas of *instruction (native-language)* and *bilingual-children (impairment)* are emerging research themes, while *speech (perception)* and *acquisition (English)* are basic research themes in SLA.

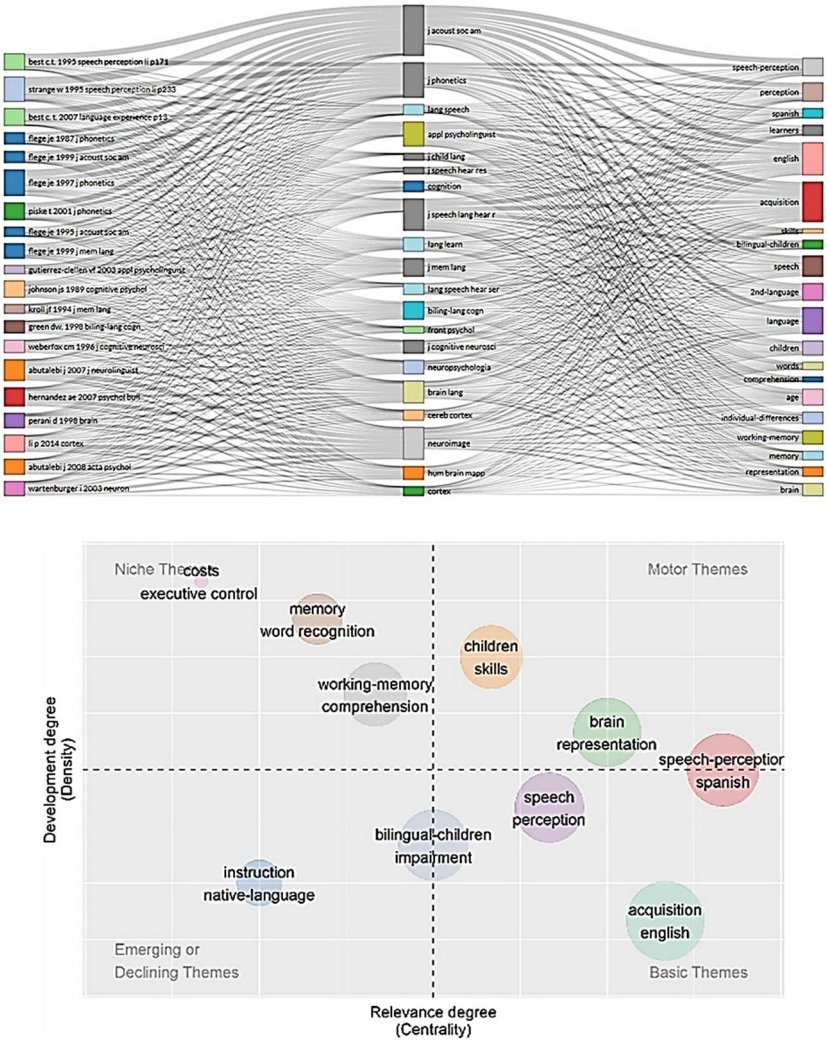


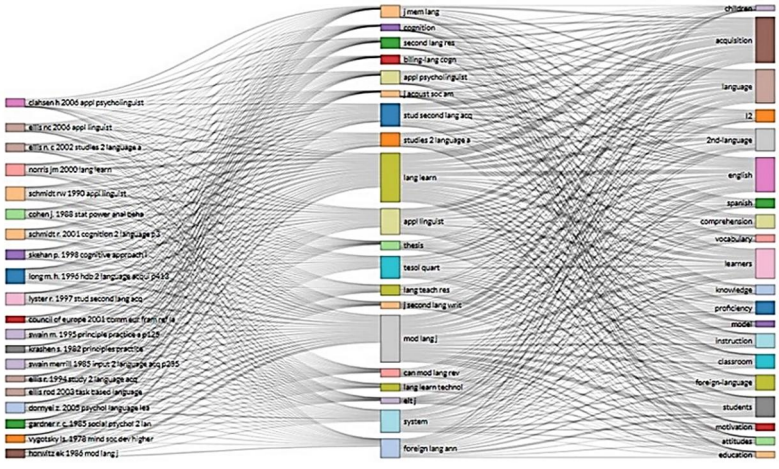
Figure 6 Intellectual flows from SLA to other disciplines of *life sciences*

Table 3 Interdisciplinary SLA studies in *life sciences*

Cited references	Citations	Cited sources	Clusters and keywords plus
Strange w, 1995, speech perception li,	31	J acoust soc am	clusters
Abutalebi j, 2007, j neurolinguist,	26	J speech lang hear r	speech-perception
Johnson js, 1989, cognitive psychol,	23	J phonetics	instruction
Piske t, 2001, j phonetics, v29, p191	23	Neuroimage	brain
Flege je, 1997, j phonetics, v25, p437	22	Appl psycholinguist	speech
Best c. T., 2007, language experience,	21	J mem lang	children
Best c.t., 1995, speech perception li,	20	Brain lang	memory
Flege je, 1999, j mem lang, v41, p78	20	Biling-lang cogn	costs
Hernandez ae, 2007, psychol bull,	20	J cognitive neurosci	working-memory
Li p, 2014, cortex, v58, p301	19	Lang learn	acquisition
Abutalebi j, 2008, acta psychol, v128,	18	Lang speech hear ser	bilingual-children
Perani d, 1998, brain, v121, p1841	18	Cognition	keywords plus:
Gutierrez-clellen vf, 2003, appl psycholing	17	Neuropsychologia	acquisition, English, language, chil-
Flege je, 1999, j acoust soc am, v106,	16	Hum brain mapp	dren, speech, perception, 2nd lan-
Green dw., 1998, biling-lang cogn, v1,	16	Lang speech	guage, age, learners, speech-per-
Kroll jf, 1994, j mem lang, v33, p149	16	Cereb cortex	ception, working- memory, brain,
Wartenburger i, 2003, neuron, v37,	16	Cortex	words, Spanish, memory, compre-
Weberfox cm, 1996, j cognitive neurosci	16	Front psychol	hension, individual-differences, rep-
Flege je, 1995, j acoust soc am, v97,	15	J speech hear res	resentation, skills, bilingual children
Oldfield rc, 1971, neuropsychologia,	15	J child lang	

4.3. *Social sciences* (refined by *language linguistics* and *linguistics* categories)

The outbound dataset of *social sciences* contains 4,959 documents, 3,597 keywords plus, 65 publication sources, and 123,198 references (see Table 1). The right panel of Figure 7 shows that there is a close interdisciplinary relationship between the SLA discipline and the disciplines in *social sciences*. As shown in the right panel of Figure 7, the interdisciplinary research themes include *acquisition (language)*, *English (students)*, *Spanish (speech)*, *learners (classroom)*, and *comprehension (knowledge)*, which are all self-explanatory and anticipatory.



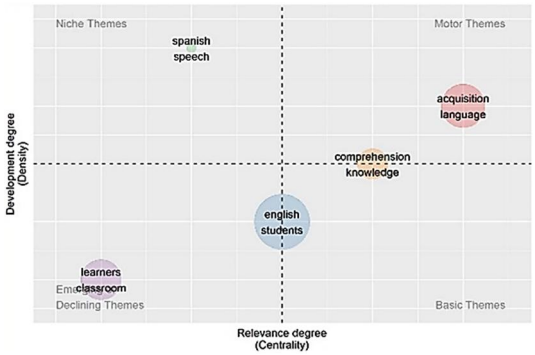


Figure 7 Intellectual flows from SLA to other disciplines of *social sciences*

Table 4 Interdisciplinary SLA studies in *social sciences*

Cited references	Citations	Cited sources	Clusters and keywords plus
Long m. H., 1996, hdb 2 language acqui	217	Mod lang j	Cluster:
Dornyei z., 2005, psychol language lea	215	Lang learn	acquisition English
Vygotsky ls., 1978, mind soc dev higher	205	Appl linguist	Spanish
Schmidt rw, 1990, appl linguist, v11	195	Tesol quart	learners
Gardner r. C., 1985, social psychol 2 lan	193	System	comprehension
Cohen j., 1988, stat power anal beha	185	Stud second lang acq	Keywords plus:
Council of europe, 2001, comm eur	169	Foreign lang ann	acquisition, language, English,
Norris jm, 2000, lang learn, v50, p417	158	Studies 2 language acq	learners, students, 2nd-language,
Skehan p., 1998, cognitive approach l	157	J mem lang	foreign-language, comprehension,
Swain m, 1985, input 2 language acq	152	Second lang res	classroom, instruction, proficiency,
Horwitz ek, 1986, mod lang j, v70	150	Appl psycholinguist	knowledge, L2, education, Spanish,
Ellis rod, 2003, task based language	141	Lang teach res	attitudes, motivation, vocabulary,
Schmidt r., 2001, cognition 2 language,	141	Thesis	model, children
Lyster r., 1997, stud second lang acq, v19	140	Biling-lang cogn	
Swain m., 1995, principle practice a	139	J second lang writ	
Krashen s., 1982, principles practice	134	Lang learn technology	
Ellis n. C, 2002, studies 2 language a, v24	130	J acoust soc am	
Ellis r., 1994, study 2 language acq	130	Can mod lang rev	
Nation isp., 2001, learning vocabulary	122	Cognition	
Johnson js, 1989, cognitive psychol, v21	119	Elt j	

4.4. *Technology* (refined by *language linguistics* and *linguistics* categories)

The outbound dataset of *technology* field contains 17 documents, 88 keywords plus, 4 publications that published the 17 documents, and 965 references (see Table 1). The left panel of Figure 8 shows the close interdisciplinary relationship between the SLA discipline and the disciplines in the academic area of *technology*. There are six research themes related to SLA in *technology*, namely, *perception (2nd language)* and *training Japanese listeners*, which are highly developed, and *acquisition (age)*, *language (American English)*, *speech-perception*, and *English* are the four basic research themes. Because there are only 17 documents

in total, there is too little data to rely on and our interpretation of these themes may deviate significantly from reality.

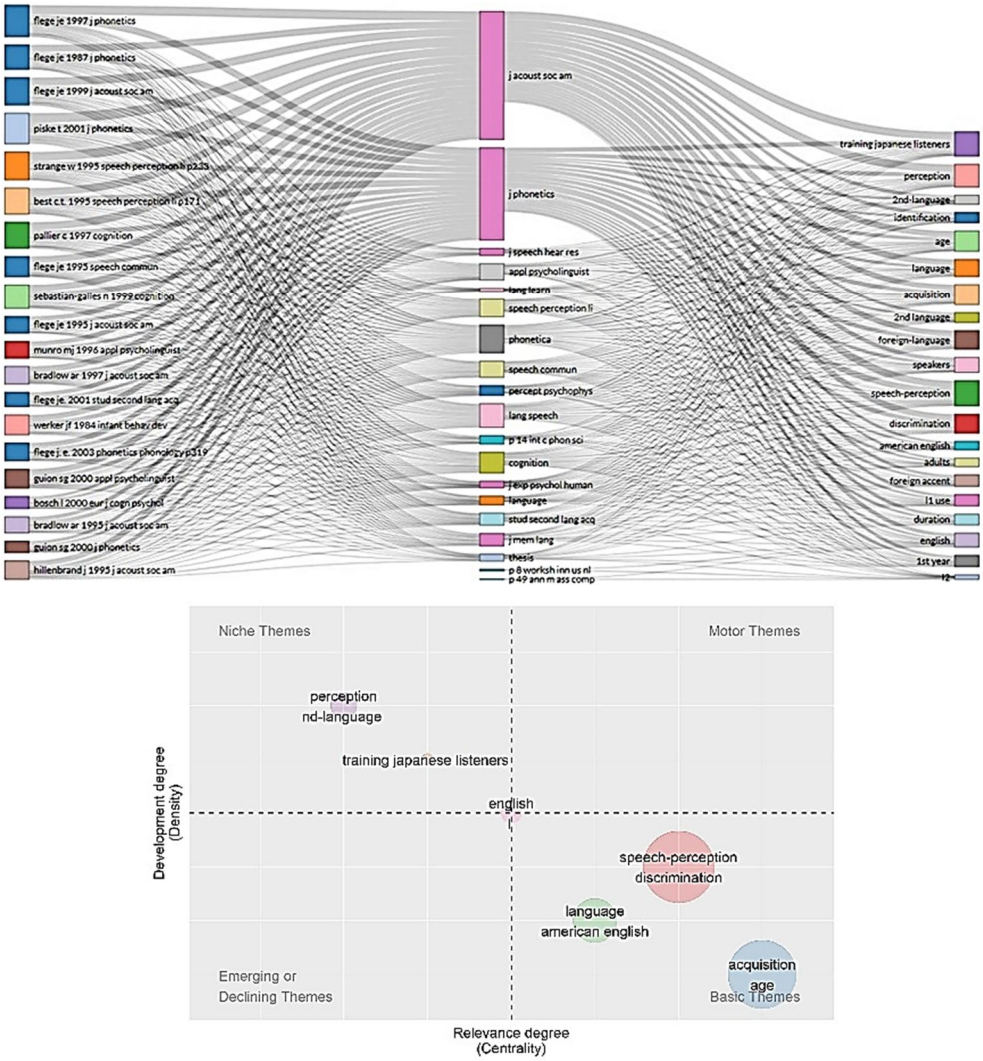


Figure 8 Intellectual flows from SLA to other disciplines of *technology*

Table 5 Interdisciplinary SLA studies in *technology*

Cited references	Citations	Cited sources	Clusters and keywords plus
Flege je, 1999, j acoust soc am, v106,	6	J acoust soc am	Cluster:
Piske t, 2001, j phonetics, v29, p191	6	J phonetics	speech-perception
Strange w, 1995, speech perception	6	Lang speech	acquisition
Best c.t., 1995, speech perception li,	5	Phonetica	language
Flege je, 1997, j phonetics, v25,	5	Appl psycholinguist	perception

Pallier c, 1997, cognition, v64, pb9	5	Cognition	training Japanese-listeners
Sebastian-galles n, 1999, cognition,	5	Speech perception li	English
Flege je, 1995, j acoust soc am, v97,	4	P 8 worksh inn us nl	Keywords Plus:
Flege je, 1997, j phonetics, v25	4	Speech commun	acquisition, speech-perception, age,
Munro mj, 1996, appl psycholinguist,	4	J mem lang	discrimination, language, perception,
Werker jf, 1984, infant behav dev, v7,	4	Stud second lang acq	training Japanese listeners, English,
Bosch l, 2000, eur j cogn psychol,	3	Percept psychophys	foreign-language, foreign accent, l1
Bradlow ar, 1995, j acoust soc am	3	Thesis	use, speakers, 1st year, 2nd-language,
Bradlow ar, 1997, j acoust soc am	3	J exp psychol human	2nd language, adults, American Eng-
Flege j. E., 2003, phonetics phonol	3	Language	lish, duration, identification, l2
Flege je, 1987, j phonetics, v15, p47,	3	Lang learn	
Flege je, 1995, speech commun, v16,	3	J speech hear res	
Flege je., 2001, stud second lang acq	3	Int conf phon sci	
Guion sg, 2000, appl psycholinguist	3	Con comp natur lang	
Guion sg, 2000, j phonetics, v28, p27,	3	Ann meet ass compt	

To answer the question concerning how research in other academic disciplines crossed over into the SLA discipline and formed new interdisciplinary research areas or sub-disciplines with existing SLA research, each inbound dataset, whose main information is presented in Table 6, was analyzed, and the results of the analyses together with three-fields plots, thematic maps, and statistics are presented in the following sections.

Table 6 Main information on inbound datasets

	Arts and humanities	Life sciences	Physical sciences	Social sciences	Technology
Sources (journals, books, etc.)	85	276	0	890	198
Documents (research papers or works)	195	846	0	6307	740
References	5537	27639	0	174675	25285
Keywords plus (ID)	182	1845	0	4510	1301

4.5. *Arts and humanities* (excluding *language linguistics* and *linguistics* categories)

Excluding the *language linguistics* and *linguistics* categories, the inbound dataset of *arts and humanities* contains 195 documents, 182 keywords plus, 85 publication sources for the 195 documents, and 5,537 references (see Table 6).

The left panel of Figure 9 shows the interdisciplinary relationship between *Arts and Humanities* and the SLA discipline. The right panel of Figure 9 shows that the academic area of *Arts and Humanities* has six themes related to SLA research, namely the well-developed themes of *children (comprehension)* and *language (speech)*, the highly-developed and independent themes of *acquisition (instruction)* and *learner (age)*, and the two most basic themes of *second language learner* and *foreign language students*.

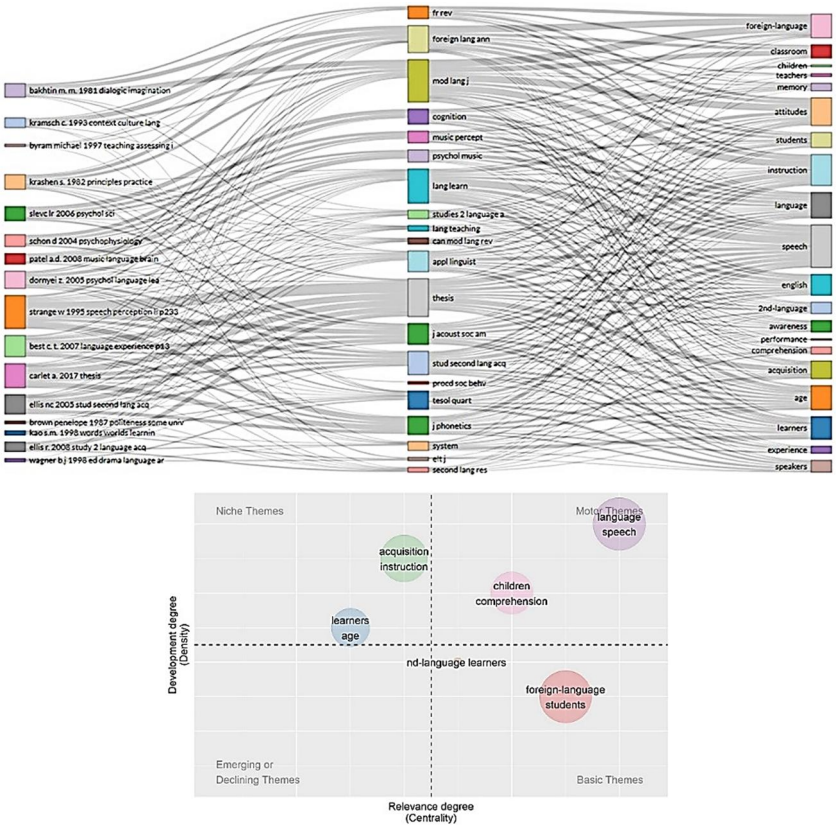


Figure 9 Intellectual flows to SLA from disciplines of *arts and humanities*

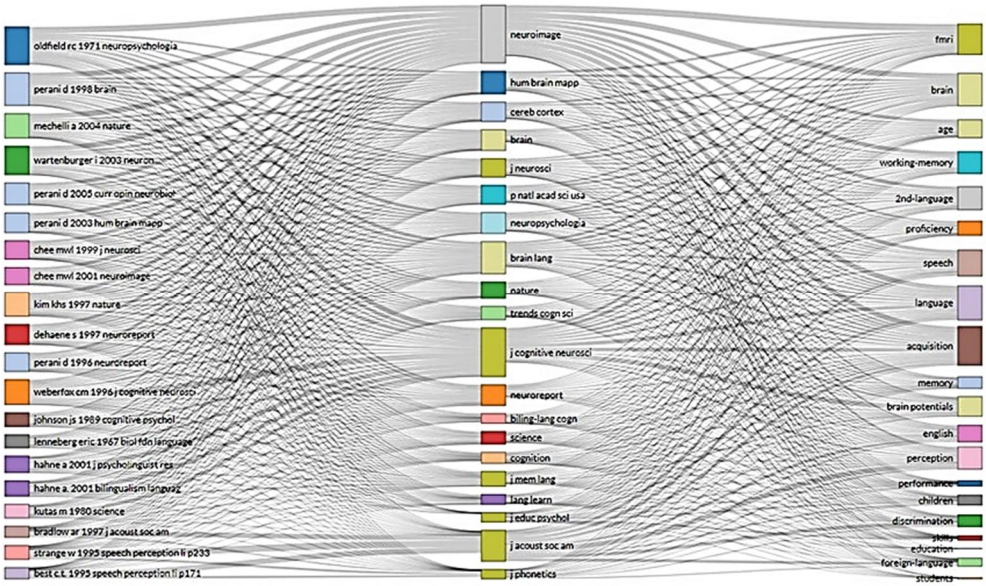
Table 7 Interdisciplinary studies in SLA formed with disciplines of *arts and humanities*

Cited references	Citations	Cited sources	Clusters and keywords plus
Kao s.m., 1998, words worlds learnin	6	Thesis	*Clusters*
Kramsch c., 1993, context culture lang	6	Mod lang j	foreign language
Strange w, 1995, speech perception li,	6	Foreign lang ann	learners
Krashen s., 1982, principles practice	5	Lang learn	acquisition
Slevc lr, 2006, psychol sci, v17, p675	5	Appl linguist	language
Best c. T., 2007, language experience	4	Tesol quart	2nd language learners
Patel a.d., 2008, music language brain	4	Stud second lang acq	children
Schon d, 2004, psychophysiology, v41	4	Fr rev	*SLA keywords plus*
Wagner b.j, 1998, drama language arts	4	System	acquisition, speech-perception, age,
Bakhtin m. M., 1981, dialogic imaginati	3	J acoust soc am	discrimination, language, percep-
Brown penelope, 1987, politeness	3	Studies 2 language a	tion, training Japanese listeners,
Byram michael,1997, teaching assessing	3	Procd soc behv	English, foreign language, foreign
Carlet a., 2017, thesis	3	Second lang res	accent, l1 use, speakers, 1st year,
Chomsky n., 1965, aspects theory synta	3	Cognition	2nd-language, 2nd language, adults,
Dornyei z., 2005, psychol language lea	3	J phonetics	American English, duration, identifi-
Ellis nc, 2005, stud second lang acq, v27	3	Lang teaching	cation, l2
Ellis r., 2008, study 2 language acq	3	Psychol music	
Lantolf j.p., 2006, sociocultural theory	3	Can mod lang rev	
Liddicoat a.j., 2013, intercultural langua	3	Elt j	
Long m., 1991, foreign language res,	3	Music percept	

The 195 documents in this dataset cite 5,537 references, and the 20 most cited references are shown in the left column of Table 7. 12 of them are important papers in the academic area of *arts and humanities*, and they are published in *arts and humanities* journals rather than SLA journals (as highlighted in grey in the left column of Table 7). Of the 20 most cited sources, 12 are of the SLA discipline (highlighted in grey under the cited sources column in Table 7), and are familiar to researchers of SLA, such as *Modern Language Journal*, *Language Learning*, *Applied Linguistics*, and others. This suggests that there are more channels for research in the *arts and humanities* to enter SLA research and to take hold as an interdiscipline or a sub-discipline of SLA.

4.6. *Life sciences* (excluding *language linguistics* and *linguistics* categories)

The *life sciences* inbound dataset contains 846 documents, 1,845 keywords plus, 276 published sources for the 846 documents, and 27,639 references (see Table 6). The right panel of Figure 10 shows that in the academic area of *life sciences*, there are 6 research themes related to SLA research, of which *bilingualism (advantage)* and *education (knowledge)* are highly-developed and relatively independent, and *children (performance)*, *brain potentials (event-related potentials)*, and *language (speech)* are the three most fundamental SLA research themes coming from *life sciences*.



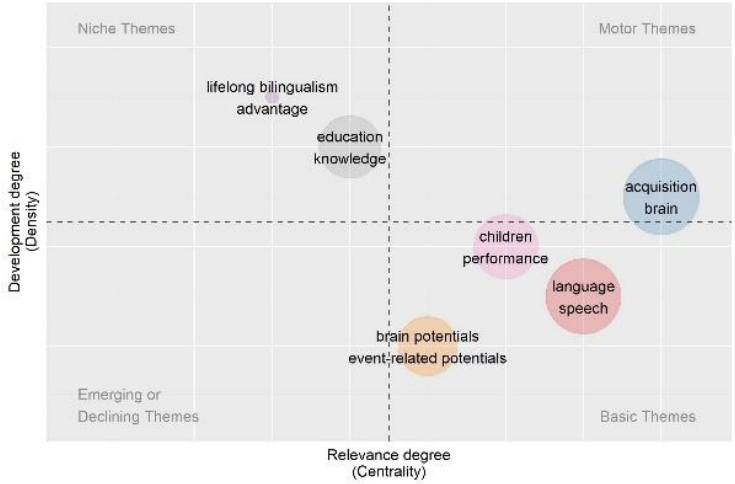


Figure 10 Intellectual flows to SLA from disciplines of *life sciences*

Table 8 Interdisciplinary studies in SLA formed with disciplines of *life sciences*

Cited references	Citations	Cited sources	Clusters and keywords plus
Oldfield rc, 1971, neuropsychologia, v9,	62	Neuroimage	*Clusters:*
Perani d, 1998, brain, v121, p1841,	58	J acoust soc am	language
Weberfox cm, 1996, j cognitive neurosci	50	J cognitive neurosci	acquisition
Kim khs, 1997, nature, v388, p171	45	Brain lang	lifelong bilingualism
Wartenburger i, 2003, neuron, v37	44	P natl acad sci usa	brain potentials
Mechelli a, 2004, nature, v431	41	Neuropsychologia	children
Dehaene s, 1997, neuroreport, v8	36	J neurosci	education
Strange w, 1995, speech perception li	36	Hum brain mapp	*SLA keywords plus:*
Perani d, 2005, curr opin neurobiol, v15	35	Cereb cortex	language, acquisition, speech, English, perception, brain, children, 2nd-language, fmri, age, working-memory, brain potentials, education, performance, memory, proficiency, students, discrimination, foreign-language, skills
Hahne a, 2001, j psycholinguist res, v30	34	J mem lang	
Hahne a., 2001, bilingualism languag	32	Brain	
Best c.t., 1995, speech perception li	31	Neuroreport	
Johnson js, 1989, cognitive psychol, v21	31	Cognition	
Perani d, 1996, neuroreport, v7, p2439	31	Nature	
Perani d, 2003, hum brain mapp, v19	31	Trends cogn sci	
Bradlow ar, 1997, j acoust soc am, v101	28	Science	
Chee mwl, 1999, j neurosci, v19, p3050	28	J phonetics	
Kutas m, 1980, science, v207, p203	28	J educ psychol	
Chee mwl, 2001, neuroimage, v13	27	Biling-lang cogn	
Lenneberg eric, 1967, biol fdn language	27	Lang learn	

4.7. *Social sciences* (excluding *language linguistics* and *linguistics* categories)

The *social sciences* inbound dataset contains 6,307 documents, 4,510 keywords plus, 890 published sources for the 6,307 documents, and 174,675 references (see Table 6). The left panel of Figure 11 shows the interdisciplinary relationship between the *social sciences* disciplines and the SLA discipline.

The right panel of Figure 11 shows that there are six themes related to SLA research in the *social sciences* field, namely, the well-developed theme of *language*

(acquisition), the highly-developed and independent theme of *fluency (accuracy)*, the emerging theme of *organization*, and the three most basic research themes of *child (knowledge)*, *English (students*), and *comprehension (working memory)*.

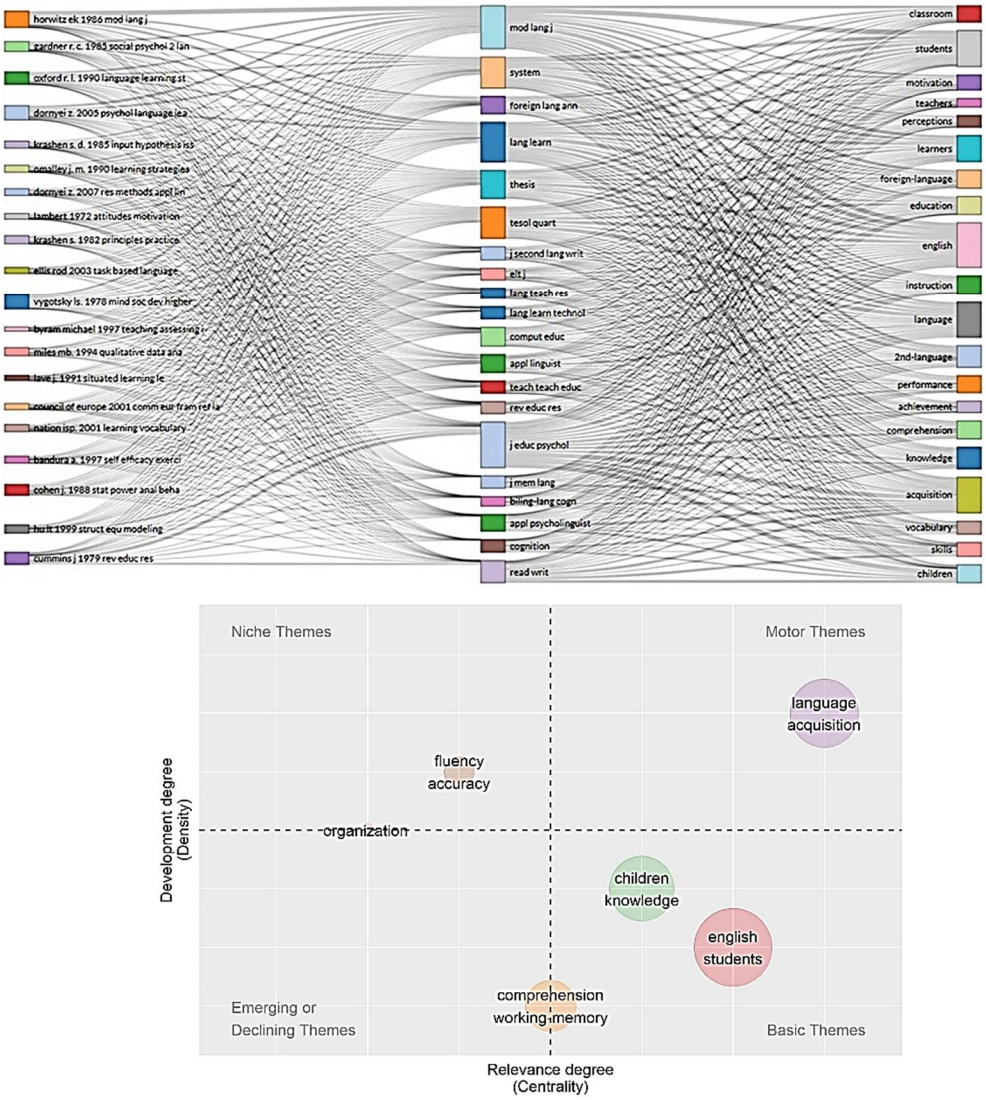


Figure 11 Intellectual flows to SLA from disciplines of *social sciences*

Table 9 Interdisciplinary studies in SLA formed with disciplines of *social sciences*

Cited references	Citations	Cited sources	Clusters and keywords plus
Vygotsky ls., 1978, mind soc dev higher	269	Thesis	*Clusters:*
Dornyei z., 2005, psychol language lea	177	Mod lang j	English
Horwitz ek, 1986, mod lang j, v70, p125	177	Lang learn	children
Council of europe, 2001, comm eur fram ref	171	J educ psychol	language
Oxford r. L., 1990, language learning st	157	Tesol quart	comprehension
Gardner r. C., 1985, social psychol 2 lan	149	System	fluency
Cohen j., 1988, stat power anal beha	146	Appl linguist	organization
Miles mb., 1994, qualitative data ana, v2	130	Comput educ	*SLA keywords plus:*
Cummins j, 1979, rev educ res, v49,	122	Teach educ	English, language, students, acquisi-
Krashen s., 1982, principles practice	120	Elt j	tion, education, learners, children,
Lave j., 1991, situated learning le	113	J mem lang	knowledge, 2nd-language, perfor-
Dornyei z., 2007, res methods appl lin	110	Foreign lang ann	mance, foreign-language, instruc-
Nation isp., 2001, learning vocabulary	99	J second lang writ	tion, comprehension, classroom,
Krashen s. D., 1985, input hypothesis iss	98	Read writ	skills, motivation, achievement, per-
Bandura a., 1997, self efficacy exerci	96	Appl psycholinguist	ceptions, vocabulary, teachers
Byram michael, 1997, teaching assessing i	92	Cognition	
Hu lt, 1999, struct equ modeling, v6, p1	92	Lang learn technol	
Lambert, 1972, attitudes motivation	89	Rev educ res	
Ellis rod, 2003, task based language	86	Lang teach res	
Omalley j. M., 1990, learning strategies	85	Biling-lang cogn	

4.8. *Technology* (excluding *language linguistics* and *linguistics* categories)

The inbound dataset of *technology* contains 740 documents, 1,301 keywords plus, 198 published sources for the 740 documents, and 25,285 references (see Table 6). The left panel of Figure 12 shows a strong interdisciplinary relationship between the Technology disciplines and the SLA discipline. The right panel of Figure 12 shows that there are 9 themes related to SLA research in the *technology* area, namely, the well-developing themes of *language (speech)*, *English (students)*, *children prefrontal cortex)*, and *mismatch negativity (speech sounds)*, two highly developed and independent themes of *intelligence (intervention)* and *corpus (engagement)*, one emerging theme of *qualitative assessment (2nd-language learners' fluency)*, and two most fundamental research themes of *words (responses)* and *acquisition (perception)*.

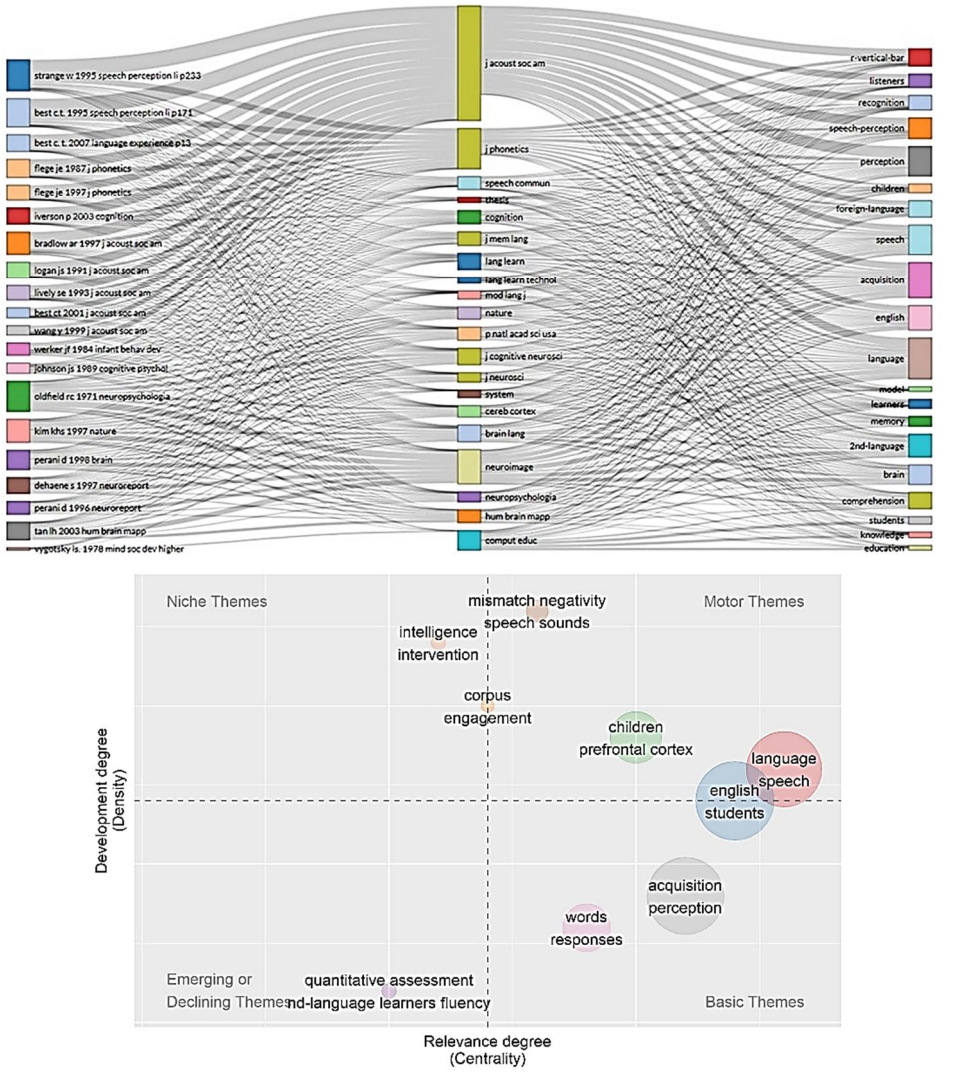


Figure 12 Intellectual flows to SLA from disciplines of *technology*

Table 10 Interdisciplinary studies in SLA formed with disciplines of *technology*

Cited references	Citations	Cited sources	Clusters and keywords plus
Strange w, 1995, speech perception li	41	J acoust soc am	*Clusters:*
Best c.t., 1995, speech perception li, p171	36	Neuroimage	language
Bradlow ar, 1997, j acoust soc am, v101	28	Comput educ	English
Best c. T., 2007, language experience	26	J phonetics	children
Oldfield rc, 1971, neuropsychologia, v9	25	J cognitive neurosci	quantitative assessment
Logan js, 1991, j acoust soc am, v89	22	Speech commun	corpus
Iverson p, 2003, cognition, v87	19	Lang learn	mismatch negativity
Kim khs, 1997, nature, v388	19	Brain lang	acquisition
Flege je, 1987, j phonetics, v15	18	Hum brain mapp	intelligence

Perani d, 1998, brain, v121	18	J mem lang	words
Lively se, 1993, j acoust soc am, v94	17	P natl acad sci usa	*SLA keywords plus:*
Dehaene s, 1997, neuroreport, v8	16	Cognition	language, acquisition, Eng-
Flege je, 1997, j phonetics, v25	15	Cereb cortex	lish, perception, speech,
Vygotsky ls., 1978, mind soc dev higher	15	Thesis	students, comprehension,
Johnson js, 1989, cognitive psychol, v21	14	Lang learn technol	education, 2nd-language,
Perani d, 1996, neuroreport, v7	14	Mod lang j	foreign-language, learners,
Tan lh, 2003, hum brain mapp, v18	14	Neuropsychologia	brain, recognition, speech-
Wang y, 1999, j acoust soc am, v106	14	J neurosci	perception, children,
		Nature	memory, model, r-vertical-
Werker jf, 1984, infant behav dev, v7	14	System	bar, knowledge, listeners

5. Discussion

5.1. Summary of findings

Over the past 20 years, SLA has emerged as an independent discipline with interdisciplinary interactions with other academic areas. In this study, by analyzing bibliometric data, I have obtained more detailed results than before. This study has distinguished two types of SLA interdisciplinary studies: (1) SLA studies entering other disciplines to form interdisciplinary studies; (2) studies from other disciplines entering SLA to form interdisciplinary studies in SLA.

Table 11 summarizes one of the interdisciplinary situations in which SLA knowledge enters the 5 academic fields defined by WoS (including *arts and humanities* and *social sciences*, where SLA itself is located), forming interdisciplines. In general, SLA has little disciplinary interaction with *physical sciences*, while for the other 4 fields, the interdisciplinary research between SLA and disciplines in *life sciences* and *technology* is much stronger and better developed than that between SLA and the remaining two fields. In the technical field, there is a strong integration with engineering and computer science. In other words, we can find a considerable number of studies that belong to these disciplines but apply SLA theory. SLA research has a strong interdisciplinary integration with brain research, neurological research, and cognitive research in *life sciences*, and with engineering and computer science in *technology*.

Table 11 SLA Interdisciplinary studies rooted in other disciplines

	Top 20 SLA references	Top cited SLA sources	SLA interdisciplinary studies in other fields
Arts & humanities	20/20	17/20	a few with: psychology acoustics
Life sciences	9/20	11/20	brain neuro

			cognition
Physical sciences	0	0	Null
Social sciences	15/20	16/20	a few with: psycholinguitics acoustics cognitive science
Technology	9/20	12/20	engineering computer sciences

Table 12 summarizes another scenario of SLA interdisciplinarity, in which knowledge from other disciplines enters the SLA discipline to form interdisciplinary studies. Table 12 shows that except for *physical sciences*, SLA research has developed such interdisciplinary research with disciplines of other academic areas. Disciplines of *arts and humanities* and *social sciences* are more likely to form such interdisciplinary research with SLA than disciplines in *life sciences* and *technology*. The results show that SLA has established strong interdisciplinary relationships with the disciplines of cultural studies, music and drama, psychology, and social psychology in the academic area of *arts and humanities* as well as the disciplines of sociocultural studies, psychology, pedagogy, and research methodology in the academic area of *social sciences*.

Table 12 Interdisciplinary studies rooted in SLA

	Top 20 non-SLA references	Top cited SLA sources	Interdisciplinary studies in SLA
Arts & humanities	12/20	12/20	Cultural studies music/drama psychology/sociopsychology
Life sciences	17/20	1/20	a few from: neuroscience brain research cognition and psychology
Physical sciences	0	0	Null
Social sciences	12/20	13/20	sociocultural studies psychology methodology education
Technology	14/20	4/20	a few from applied studies of: neuroscience brain research cognition/psychology

5.2. On SLA in other disciplines

There has been little research in the past that would have looked at SLA as a provider of knowledge in forming interdisciplines. This study has found that the SLA discipline has not contributed much to the disciplines in the academic areas of *arts and humanities* and *social sciences* but has taken root in some disciplines of *life sciences* and *technology*. The interdisciplinary studies that originated from SLA have contributed to the development of these disciplines.

The finding that the SLA discipline does not contribute much to *arts and humanities* and the *social sciences* is not surprising as it has just echoed the statements made in the past (Gass, 1993; Klein, 1998). However, previous research has either not investigated the reasons for the SLA's lack of contribution to other disciplines, vaguely attributing it to SLA's reliance on theories from other fields (Gass, 1993), or suggested that SLA researchers themselves did not have expertise in multiple disciplines, resulting in SLA research actually being carried out by different researchers using methods from different disciplines (Liddicoat, 2010). There were other studies (Atkinson, 2011; Dakowska, 2013) that provided more evidence of SLA making little contribution to other disciplines. Dakowska (2013) derived her findings from a review of the development of SLA in the cognitive discipline, while Atkinson (2011) found this by looking at the sociocultural identity, and language socialization approaches that had emerged in SLA research. However, the academic areas examined in the studies were too close to the domain in which SLA was situated. Furthermore, Chen (2018), using a bibliometric approach to study the development of SLA, found that the influence of SLA on other disciplines did had not increased much in the past 30 years. Similar conclusions were drawn from the above-mentioned studies probably because the researchers tried to explain SLA interdisciplinarity within the SLA discipline itself or within fields slightly larger than SLA, such as applied linguistics, and none of them took a stance on other disciplines more distant from the SLA discipline. This resulted in incomprehensive explanations of SLA interdisciplinarity by previous research.

In this study, the original search records were subject to further processes before outbound datasets and inbound datasets were generated, which led to a better explanation of SLA interdisciplinarity. However, the classification of subject categories in WoS was not perfect. This is because the same search record of SLA may be assigned to the category of *language linguistics* and the category of *linguistics* under *arts and humanities* and *social sciences*, respectively, which resulted in some duplicate categories being created. I used Bibliomatrix's own cleaning function to remove duplicate papers to ensure that each paper in each inbound and outbound academic area dataset is a single record with no duplicates. However, the same paper may also appear in the datasets of different academic

areas. For example, the findings (see Table 11) show that SLA forms an interdiscipline related to acoustics in the academic area of *arts and humanities* and another interdiscipline related to acoustics in the academic area of *social sciences* at the same time. The impact of multiple classifications on the results of this study, although not negligible, is relatively limited for the following reasons:

1. Using three-field plots and thematic mappings, I am mainly focused on analyzing the references of the papers, which in each of the dataset are usually more than ten or twenty times the number of the papers themselves (as can be seen from Tables 1 and 2).
2. The circulation of theories or knowledge in SLA studies is not unidirectional in itself, and very often it is likely to be bidirectional or multidirectional, especially in terms of references. In other words, even if a paper is not classified into a certain category, other similar papers may still be classified into this category, and all the references contained in all the papers retrieved play a bigger role than the papers themselves.
3. The threshold occurrence set for three-field plots will only promote papers that are highly cited. If the interference of multiple classification is not a large-scale problem, its impact would be small.
4. As bibliometrics studies use quantitative data, they are naturally less precise than literature analysis performed manually.

As pointed out by many scholars and one of the anonymous reviewers of this paper, it is possible that articles published in journals of a discipline including SLA are completely unrelated to the discipline. For example, 18 SLA papers were found to be incorrectly classified by the WoS system into the *food science technology* category when one of the reviewers of this paper used the same search query as the one benefited from in this article. It is likely that similar situations may occur in other categories and that some articles published in SLA disciplinary journals may not be related to SLA. There is no way to exclude such cases except by manual reading and filtering. I manually checked the search results and confirmed that all the papers retrieved were indeed related to SLA, but I would not be involved in classification or reclassification of them into a different discipline. Therefore, it is important to carefully interpret the findings when such a situation arises, particularly in the case of disciplines that are distant from SLA. In addition, I followed the WoS classification only as an operational and tentative approach accepting that it may be inaccurate in some cases, but hopefully academic classification systems such as WoS will be improved in the future.

Another possible reason for the perceived lack of contribution of SLA to other disciplines is that the early disciplinary development of SLA was characterized by

the integration of knowledge, theories and methods from neighboring disciplines (Dixon et al., 2012; Gass et al., 2013), and the degree of integration increased throughout the development process to the extent that it may be difficult to distinguish which is the theory and method originating from SLA itself. In addition, researchers have different views on the disciplinary identity of SLA – applied linguistics, educational linguistics, or cognitive science (Holbrook, 2013). This naturally makes it difficult to distinguish between SLA theories and theories from other disciplines. This study has adopted the WoS categorization system to define the SLA discipline and other disciplines from the level of academic areas and thus provided some new insights into SLA interdisciplinarity in different academic areas. Since the subject categories of WoS do not correspond to specific disciplines, the data was filtered manually. If more refined subject categories emerge in the future, the interdisciplinarity of SLA should be re-investigated.

Of course, an idealist and comprehensive way to study the interdisciplinarity between disciplines is to compare all the works without pre-selection. At present, search engines such as WoS, Scopus, Semantic Scholar, ResearchGate, and Google Scholar can only do a limited part of the work. This study has retrieved papers related to SLA first and then retrieved the references cited by the papers, which is the search method used by most bibliometric studies. However, some papers that are not apparently related to SLA (not returned by topic search) but are actually very relevant are bound to be missed, and the references cited in this study are missed as well. Therefore, the results of this study should be interpreted with the caveat that some interdisciplinary studies may not have been identified.

5.3. On other disciplines in SLA

The results of this study indicate that a great deal of knowledge has flowed into the SLA discipline from disciplines under *social sciences* and *arts and humanities*, especially from psychology, cognitive psychology, sociopsychology, which made the greatest contribution to SLA interdisciplinarity, and that research in the academic areas of *life sciences* and *technology* has made little contribution to SLA interdisciplinarity.

The interdisciplinarity of the SLA discipline has arguably been one of the main concerns of researchers (Klein, 1998; Kramsch, 2003; Leung et al., 2019; Neupane, 2019; Ortega, 2013, 2018; Tarone, 2015). However, the account of the interdisciplinarity of SLA has been mainly based on general observations and summaries, and it has been basically a subjective judgment as to whether knowledge, theories or methods from other disciplines have constituted interdisciplines of SLA. As a result, we have seen many inaccurate descriptions of the interdisciplinarity of SLA, resulting in a vague impression of SLA as if it is an all-encompassing

discipline. For example, today's SLA research has been integrated into cognitive science, neuroscience, computer science, etc. Can we consider SLA to have formed interdisciplines with these disciplines? Some scholars have been cautious about this assumption, arguing that the current interdisciplinarity and academic validity of SLA is unclear since many of the so-called SLA interdisciplines are not strictly interdisciplinary (Kramsch, 2003; Liddicoat, 2010).

The findings obtained from the present study support this cautious view (Kramsch, 2003; Liddicoat, 2010). There are some interdisciplinary interactions between SLA and some emerging disciplines mainly in *life sciences* and *technology*. However, these interactions are much weaker than those between SLA and cultural studies, psychological studies, sociopsychological studies, and sociocultural studies, which have already been established as interdisciplines or subdisciplines in SLA research. The most important evidence of this is that the research outputs of the former are largely published in non-SLA mainstream journals, as shown in Table 12, where only one SLA professional journal is among the top 20 published sources citing references in *life sciences*. Therefore, in a strict sense, the former can only be described as studies in the areas of *life sciences, social science* or *technology*. Research within a discipline that is consistently published and cited in journals of its own discipline cannot be regarded as interdisciplinary research.

Another important finding of this study is that the methodology from the academic area of social sciences has become a prominent interdisciplinary study of SLA (see Table 12). Such a result has reinforced the status of SLA as an independent discipline. Although SLA has long been declared an independent discipline (Gass, 1993), the view has been contentious over the years, with some viewing it as a branch of applied linguistics, part of educational linguistics, or a branch of cognitive science (Holbrook, 2013). Some researchers suggest that SLA has already become an autonomous field of study (Neupane, 2019), while some claim that the research methods of SLA are sound (Klein, 1998). There are also a number of publications that have focused on SLA research methods (Plonsky, 2015). But, after all, there has been no special study on SLA's methodology. According to Kuhn (1970), for a subject to become an independent discipline, it must have its own methodology, evaluation system, and theory system. This study has found that SLA incorporates methodologies from the *social sciences* in the process of forming an interdiscipline, which provides strong empirical evidence to support the view that SLA is an independent discipline and helps to resolve some of the debates about the disciplinary status of SLA. With the establishment of SLA's independent disciplinary status, we can expect that the interdisciplinary connections between SLA the disciplines in the social sciences will be further strengthened, which will make a contribution to the healthy development of SLA.

6. Conclusions and recommendations

Although SLA was regarded as applied linguistics at the beginning of its development and was influenced by linguistics, it has gradually developed into a multidisciplinary and interdisciplinary discipline in its own right. In today's rapidly evolving science, the intersection of multiple disciplines in SLA has led to the creation of new interdisciplinary disciplines. This study has investigated the SLA disciplinary development from the perspectives within the SLA discipline and within other fields, using a bibliometric approach. The results of this study have shown that SLA acts as both the intellectual provider and the recipient of knowledge in an interdisciplinary context. In the former case, SLA research flows into the academic areas of *life sciences* and *technology* to form SLA-originated interdisciplinary research with disciplines representing the two areas, such as brain research, neurology, cognition, computer technology, and engineering. In the latter case, SLA receives knowledge transferring from the academic areas of *arts and humanities* and *social sciences* to consolidate existing interdisciplinary research in SLA. New insights are also presented in response to some existing discussions on the disciplinary and interdisciplinary identity of SLA, which will hopefully contribute to a clearer understanding of the interdisciplinarity of the discipline.

Although it is impossible to present the whole picture of SLA and predict its future development due to the dynamic nature of scientific advances, SLA research has been nurtured by behaviorist, innatist, cognitive and sociocultural theories, and has gradually matured as an independent discipline. However, there are still a lot of differences and controversies in the SLA discipline ranging from disciplinarity, interdisciplinarity, and SLA theory to research methodology. To sustain the healthy development of SLA, researchers need to pay more attention to its disciplinary and interdisciplinary nature, and enhance the depth of research. In addition, compared to linguistics (applied linguistics) and other disciplines in the humanities and social sciences, SLA has not been given a high academic status, and efforts are needed to make SLA a discipline that will receive more recognition.

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