ENGINEERING STUDENTS' SELF-EFFICACY IN HIGHER EDUCATION: A REVIEW OF THE LITERATURE

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Abstract. Using the Systematic Quantitative Literature Review method, this paper reviewed the literature related to engineering students' self-efficacy in higher education from 2010 to 2020 to evaluate the existing research and suggest directions for future work. One hundred and thirty-five articles were selected for the review of the most popular research topics and four patterns of the distribution of studies, namely countries, methods, and study samples. The most popular research topics worldwide were learning performance and self-efficacy, self-efficacy and gender/race, preservice teachers' self-efficacy, and self-efficacy and entrepreneurship. Few articles investigated engineering students' self-efficacy in English language learning, online learning, or E-learning in the last decade. Most reviewed studies were either conducted in the USA or high-income countries and administered in single research settings. Quantitative methods outnumbered qualitative or mixed-method research. Undergraduates were the most researched participants, followed by a mix of graduates and postgraduates. The review includes only articles but not presentation papers, dissertations, and book chapters, thereby reducing the coverage of the existing research on engineering students' self-efficacy in higher education.

Keywords: engineering students, self-efficacy, higher education, review

1 INTRODUCTION

In recent years, industrial engineering will no longer only need staff with a single skill in this information explosion era. The cultivation of interdisciplinary talents has become one of the focuses of higher education today in the world. The industries' demands are changing and present challenges to higher education in producing the future workforce. Engineering students need to develop their sustainability literacy (knowledge, competence, values, and attitudes related to sustainable development) and quickly adapt to new engineering technologies (Kastenhofer et al., 2010). In the fields of science and engineering education, steps are seriously taken to recruit students and retain them until they complete their degrees to meet the demands of the workforce (Hussain et al., 2022).

Recently, researchers have studied the factors that foster the learning motivation of engineering students in higher education (e.g. Hsieh et al., 2012; Wolters & Benzon, 2013) The concept of self-efficacy, i.e. the beliefs people hold for their abilities to do certain tasks (Bandura, 1997) or the assessment of individuals' abilities and potentials to accomplish specific learning goals (Jiang et al., 2017), has been applied in many different fields, including health, counselling, business, sciences, and education since it can predict individuals' behaviors, motivation, and affective states (Hsieh et al., 2012). Engineering students' self-efficacy, that is, students' beliefs in their capabilities to learn and perform a variety of engineering tasks successfully (Mamaril et al., 2016) has been known to be positively associated with performance and persistence. Self-efficacy is related to what students believe they can do with the required knowledge and skills to complete the tasks (Klassen & Klassen, 2018). Self-efficacy beliefs predict students' academic performance and have a positive correlation with their retention (Bartimote-Aufflick et al., 2015). If engineering students have a high level of self-efficacy toward a task, they may get more effort, have a positive attitude, be more persistent in the face of difficulties when completing the task, and often set up a plan to reach high goals. In contrast, if they have a low level of self-efficacy, they may reduce their efforts to complete the task, or even quit. Students who display higher self-efficacy beliefs in the engineering field tend to work harder than those with lower self-efficacy levels and have better plans to pursue engineering

careers (Jones et al., 2010).
Self-efficacy has attracted significant attention in the literature (Fantz et al., 2011) owing to its predicting power. Several efforts have been made to review research examining self-efficacy in education (see, for example, (Tümkaya & Miller, 2020; Unal & Tasar, 2021)). However, relatively little research has investigated engineering students' self-efficacy despite its contribution to students' achievements, success, and intentions to persist in the learning area. There is no literature review examining the studies on this topic, especially in higher education, resulting in no idea about areas lacking research. In this review, we conducted a systematic review of the studies on engineering students' self-efficacy in the field of higher education. The review aims at evaluating the existing literature, showing the gaps and current trends, and suggesting directions for future work. The following questions guided the current review:

1. What are the most popular research topics in the existing engineering students' self-efficacy studies?
2. What pattern does the distribution of studies have across countries, methods, and study samples?

2 METHOD

This paper reviews the research on the self-efficacy of engineering students in higher education over the past 10 years. The Systematic Literature Review Method adopted in this paper has been widely used in different research fields (Green et al., 2006; Moreno-Marcos et al., 2019) to analyze and discuss relevant articles that have been published in the engineering students' self-efficacy literature. The method is considered an effective way to review literature since it enables the replication of search processes. Systematic literature reviews follow five typical steps: formulating research questions, conducting systematic searches, assessing the quality of relevant studies, synthesizing and interpreting data (Moher et al., 2015).
The second author used the university library system to search for relevant studies. The Library and Information Center at National I-Lan University (NIU) has a search system named "Jumper, Hybrid Discovery Service and Data Analysis Platform" (Figure 1) which integrates electronic resources (including databases, e-journals, and e-books), providing users with a single platform for querying, full-text download, browsing, and management functions. This system includes 159 databases such as ABC-CLIO/Greenwood, ACS (American Chemical Society), ASME, and EI Village (Compendex). Advanced searching was adopted in this paper. In the advanced searching mode, there are three searching keywords and seven searching modes. Researchers can freely arrange searching keywords and searching modes. The first author searched for three keywords: "Self-efficacy", "Engineering", and "Higher education". Higher education was then replaced by "Higher education", "Education", "University", and "College". Moreover, the search included the work from 2010 to 2020 and did not limit the language of the studies.

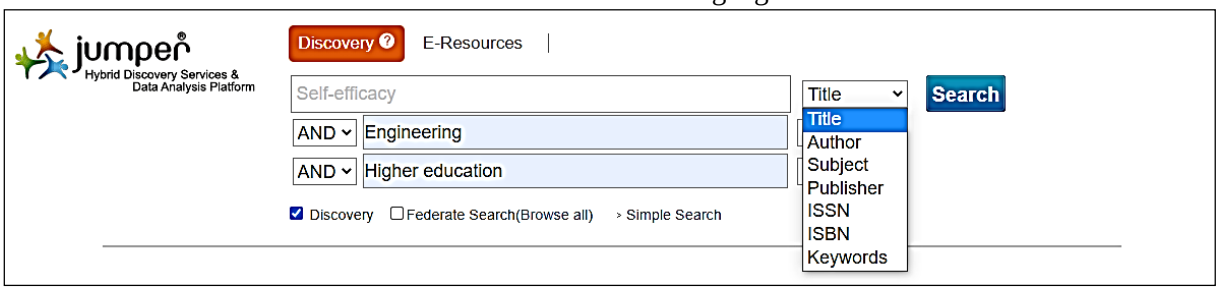

Figure 1: Jumper system in NIU library.

3 RESULTS

There were 935 articles in the search results. After duplicate articles were removed, there were 264 articles. The second author then read the abstracts in each article carefully to determine whether they were discussing the self-efficacy of engineering students. Based on the search results, one hundred and thirty-five articles were selected. Figure 2 presents the number of articles searched after filtering from various databases. The database from Education Resources Information Center (ERIC) had the largest number of articles with a total of 72 articles, followed by IEEE Xplore Digital Library and Complementary Index with 33 and 10 articles respectively. Others represent a total of 9 databases, including ScienceDirect, Academic Search Elite, and Korea Citation Index.

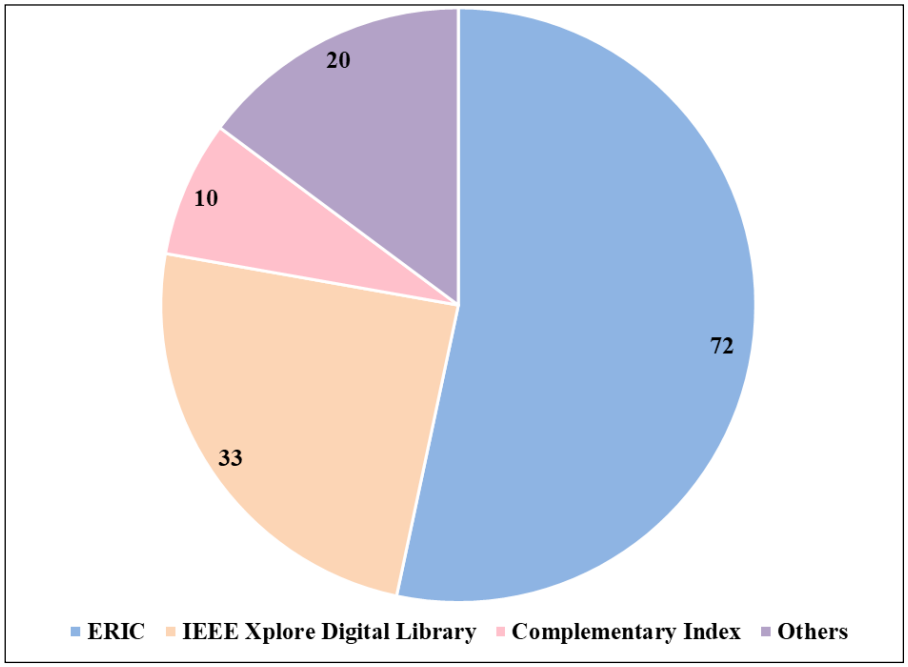

Figure 2: Top database in the literature searching

3.1. The most popular research topics in the existing engineering students' self-efficacy studies

Figure 3 shows that the most popular research topic worldwide is learning performance and self-efficacy. Researchers in this topic investigated the effects of self-efficacy levels on the learning performance of engineering students and how to improve learning performance depending on each self-efficacy level. Generally, high levels of self-efficacy led to better learning results or vice versa. A number of suggestions were made to improve students' grades, including measures to develop a stronger sense of self-efficacy in the students. For example, Ganguly et al., (2017) examined the relationship between four influencing factors (attribution, stress, self-efficacy, time management) and academic performance of Indian engineering undergraduates. The authors compared two age groups, a sample of 372 freshmen and another sample of 232 juniors, sophomores, and seniors from the same college, to assess the effect of developmental change on the influencing factors of academic performance. Two studies were conducted with two participant groups. The researchers discovered that a positive relationship between self-efficacy and grade goals was found in their studies. Time management and academic self-efficacy led to higher learning scores for students in both groups.

The next popular research topic is self-efficacy and gender/race. In this category, researchers studied whether there were significant differences in the self-efficacy levels of different groups of engineering students. Some of the researchers looked at the improvement of the self-efficacy of disadvantaged engineering student groups. For example, Stump et al., (2011) conducted two studies with student participants learning Mechanical and Aerospace Engineering at a university in the U.S. to test the intercorrelations between self-efficacy, motivation, collaborative learning strategies, and achievement. In study 1, one hundred and fifty engineering students answered the survey which examined a correlation between collaboration, self-efficacy, knowledge-building behavior, and course performance. One key result was that self-efficacy and collaboration significantly predicted course performance. In study 2, five hundred and thirteen students were surveyed. The main aim of study 2 was to explore gender similarities and differences in self-efficacy and learning collaboration. The researchers found out that student collaboration was positively associated with self-efficacy and course grades.

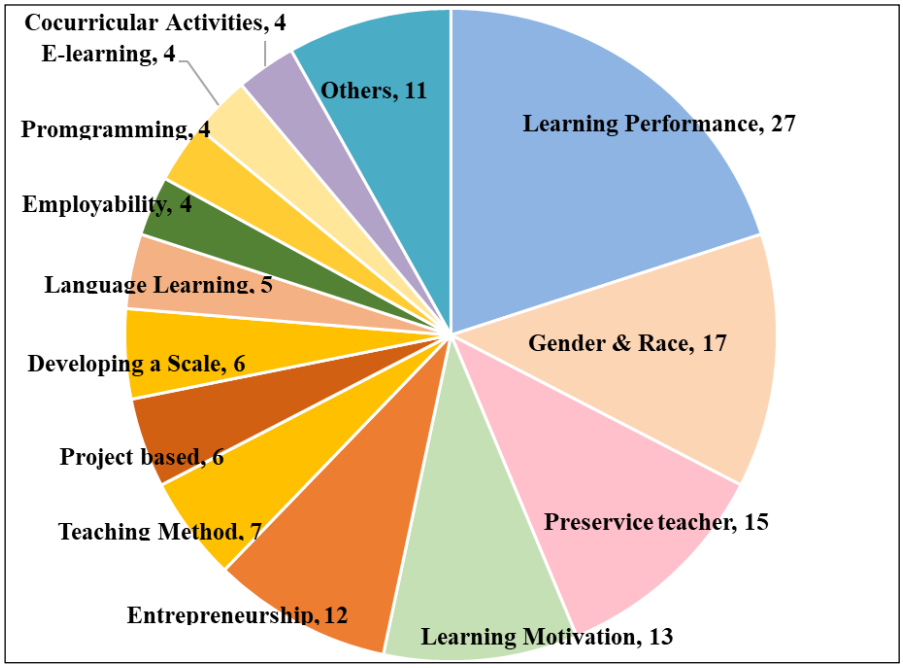

Figure 3: The most popular research topic s worldwide

Another popular research topic is preservice teachers' self-efficacy. Most studies investigating this topic measured the self-efficacy levels of engineering student teachers or changes in their self-efficacy after joining a course or a program. For example, Kaya et al., (2020) compared the efficacy beliefs of preservice science teachers before and after they joined a three-week teaching methods course. Thirty-five participating elementary student teachers (30 females and five males) from a public university in the U.S. answered a questionnaire survey at two different points of time in this exploratory research. After their exposure to certain activities, including coding programs, building robots, and solving puzzles, the preservice teachers gained more confidence in computational thinking. This research found that an intervention of a teaching methods course had the potential of increasing the teaching self-efficacy beliefs of preservice science teachers.

The next common topic is self-efficacy and entrepreneurship. Interestingly, more than half of the research in this area was written by scholars from ESL countries and employed engineering students in ESL countries as participants. Many articles in this category mentioned ways to improve ESL engineering students' entrepreneurship self-efficacy through lectures or curricula or suggested the positive relationship between career development and entrepreneurship self-efficacy. For example, For example, Jiang et al., (2017) used two questionnaire surveys to research the relationship between entrepreneurial education quality, self-efficacy, and intention in science learning areas of college students. The first and second surveys received a total of 318 and 258 valid questionnaires respectively. Results show that self-efficacy predicted the relationship between the quality of entrepreneurship education and entrepreneurial intention. Entrepreneurial orientation positively affected the relationship between the quality of entrepreneurship education and self-efficacy.

In our search of the studies, there have been 5 articles that examined self-efficacy and English language learning. Researchers investigated the relationship between sources of self-efficacy information and engineering students' English proficiency levels. One of them is the study of Idrus et al., (2013) which aimed to investigate the self-efficacy level of technical trainees of an oil and gas training institute who spoke English as their second language, based on their background. The participants for this study were 469 students from an oil and gas training institute in Malaysia. Researchers stated that self-efficacy beliefs emerged primarily through the main sources of self-efficacy information suggested by Bandura (1997): mastery experiences (past performances), vicarious experiences (task observation), social persuasion (feedback or support), and physiological states (emotions). This paper suggested ways to engender participants' self-efficacy in English oral communication based on the four efficacy sources.

Not many articles or dissertations have been focused on engineering learners' self-efficacy in higher education in online learning or E-learning, especially in the MOOCs field in the last decade. There have been only 4 articles discussing the topic. For example, Sun & Rueda (2012) used an online survey to investigate the impact of three variables (situational interest, computer self-efficacy, and self-regulation) on engineering student engagement in an online learning context. A total of 203 students (67 females and 135 males) in the School of Gerontology and Engineering in the U.S. participated in the survey. Interest and self-regulation were shown to be significantly predicted student engagement. However, computer self-efficacy was not correlated with engagement. The authors noted the mediating role of instructor support and acquired skills in the relationship between computer self-efficacy and student engagement.

3.2. Research locations

Our search shows that studies investigating engineering learners' self-efficacy in higher education were carried out in 23 countries (Figure 5). Most studies were conducted in the U.S. (n=98) or in high-income economies (n=14). Very little research in the same area was carried out in other developing countries, especially in Asia. Only two studies were conducted in the intercultural context (Chen & Phan, 2021; Edalatifard & Prieto, 2016).

3.3. Methods

Most studies in the review used quantitative methods. In articles using quantitative methods, questionnaires (paper and pen surveys, questionnaires, surveys) were used (e.g. Chian, 2018; Olango, 2016). Only five of the reviewed articles used mixed-method design (e.g. Aleta, 2016; Lackéus, 2014; Naji et al., 2020; Purzer, 2011; Verdín et al., 2021), and only three of the articles used qualitative methods (observation, documentation, interview) (Hirshfield, 2018; Riney & Froeschle, 2012; Wooditch et al., 2018). Surveys and interviews were used in mixed-method studies (e.g., Aleta, 2016; Purzer, 2011). More than half of the studies (n=70) included scale adaptation from other research (e.g. Barron & Amorós, 2019; Concannon & Barrow, 2012; DeChenne et al., 2012; Kaya et al., 2019; Mahasneh et al., 2020; Sun & Rueda, 2012). Most of the studies are generally based on relational designs or a single questionnaire. Question items were students' self-report rating scales.

3.4. Study samples

When one hundred and thirty-five studies are examined, eight studies were carried out with both undergraduates and postgraduate students (Chen et al., 2015; Iraola-Real et al., 2019; Jiang et al., 2017; Kaya et al., 2020; Khan & Ibrahim, 2017; Lackéus, 2014; Lent et al., 2010) while only four were conducted with graduate students (master degree's students, doctoral or postdoctoral candidates (Bernstein et al., 2016; Jiang et al., 2017; Jungert & Rosander, 2010; Kaya et al., 2019);. A small number of researchers invited freshmen (n=8) and seniors (n=2) (Yesilyurt et al., 2021; Çeliker, 2020) as research participants. The rest of the studies (n=113) employed engineering undergraduates as participants (e.g. Ganguly et al., 2017; Hsieh et al., 2012; Mamaril et al., 2016; Sui et al., 2017) . All studies recruited participants from different fields.

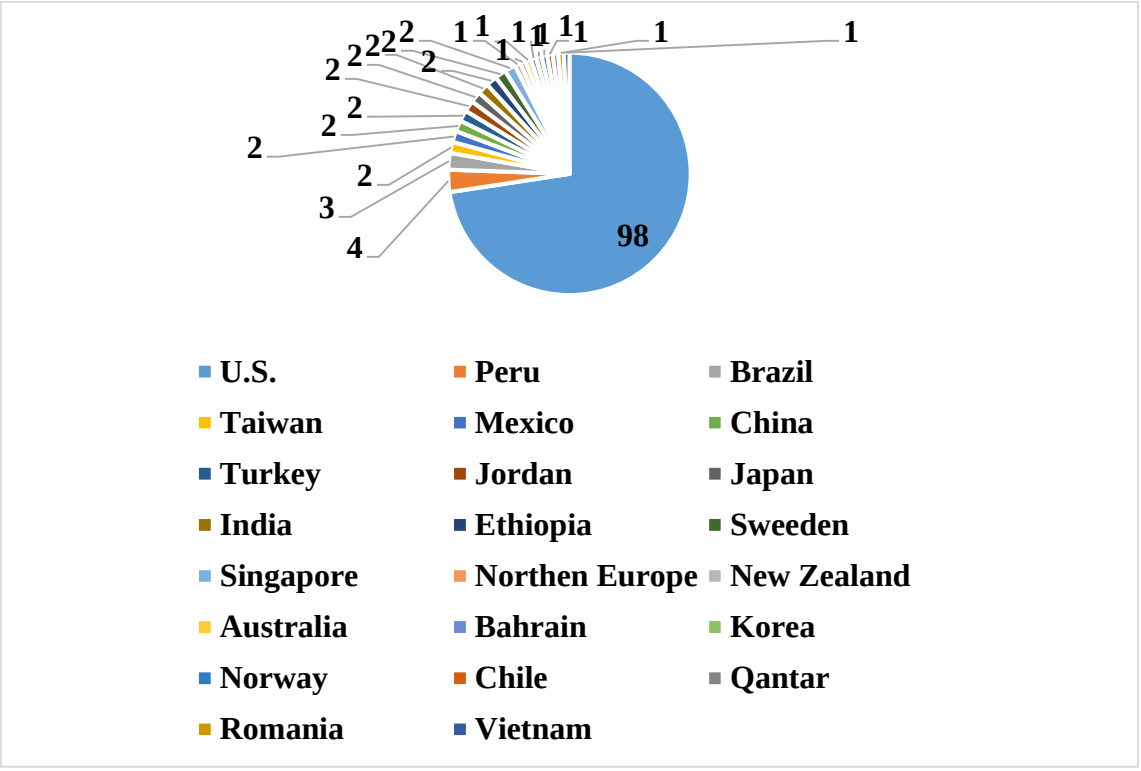

Figure 5: Countries

4 DISCUSSION AND CONCLUSION

As stated elsewhere in this review, self-efficacy beliefs are possibly one of the major factors that need to be seriously considered in engineering education. Research focus has not been placed on engineering students' self-efficacy in the available self-efficacy literature (Furse, 2019). Our review has shown that although the number of studies on the domain has increased over the years, it is still insufficient due to its limited number of studies, research topics, the distribution of countries, methods, and participants.

When the most popular research topics are examined, there is a need for self-efficacy research on online learning, E-learning or English language learning of engineering students. In this era of information explosion and globalization, online learning has become popular and contributed a significant part to the lifelong education of engineering students (Sun & Rueda, 2012). In addition, as education has shifted from traditional classes to an online environment under the effect of the COVID-19 pandemic, the role of online learning and/or MOOCs (Massive Open Online Courses) has become critical (Hodges, 2016). In order to get benefits from online courses, ESL engineering students are expected to obtain good English language skills. English communication skills are the key to success for engineers who wish to develop in advanced societies. Therefore, more research on the topics of online learning and E-learning is preferable.

One of the findings of the review is that a majority of the studies reviewed were conducted in the USA and high-income countries (e.g., Korea, Taiwan and Sweden). Very few authors came from or conducted research on engineering students' self-efficacy in developing countries. Therefore, we stress the need for researchers to conduct more research in these countries so that insight into this phenomenon can be given. Engineering educators need to have enough evidence of what experiences impacting on engineering students' self-efficacy beliefs in order to develop or revise their existing education programs.

Another remarkable finding is that most of the studies were conducted in single settings. Only two studies were cross-contextual. In the fast developing scientific and technological field, each country has its own comparative advantages, challenges, and successful models. Comparative studies may help to understand the relative self-efficacy beliefs of engineering students in different education systems. In addition, culture is considered a major contextual factor influencing self-efficacy (Bandura, 1997). Thus, more studies from a cross-contextual perspective can possibly provide a better understanding of the development of engineering students' self-efficacy, and how cultural differences affect self-efficacy beliefs.

When the methods of the articles in the review were examined, quantitative studies outnumbered qualitative or mixed-method research. In addition, most of these quantitative studies are based on a single questionnaire. Questionnaires offer a quick and economical way to get results. However, obtaining results from a single questionnaire has some limitations in understanding self-efficacy beliefs. Self-report questionnaires may result in invalid responses. Respondents may not provide accurate answers owing to uncomfortable feelings or misinterpretations of questions (Seleva, 2017). The validity of respondents' answers cannot examine because there is no opportunity for elaboration or in-depth understanding of the phenomenon (Creswell, 2012). In addition, though participants can answer several questionnaires at different points in time, Likert-scale instruments have little or nothing to do with the understanding of the influence of contexts on self-efficacy or how self-efficacy changes over time (Wyatt, 2012). Accordingly, using a single questionnaire to get results creates a serious threat to the future of self-efficacy research in engineering education. Wyatt (2012) suggested the use of mixed methods and qualitative research designs in self-efficacy studies to understand the nature, development, relationship, and effects of self-efficacy. Therefore, it is advisable that more in-depth studies using mixed-method or qualitative designs be carried out in the future.

The review also points out that undergraduates were the most researched participants, followed by a mix of graduates and postgraduates. We found a paucity of self-efficacy research on a single group of student participants. In essence, the one-group research design is cost-effective and time-saving compared to other research designs. Researchers in developing countries, therefore, may want to apply this design in their future work. In addition, another benefit of one-group design is that it allows for long-term follow-up and detailed examinations of patterns of changes and their effects over time (Knapp, 2016). Different settings and context can lead to changes in self-efficacy (Bandura, 1997), and longitudinal studies are preferred in self-efficacy literature owing to the development nature of self-efficacy. Thus, this type of research design is worth the attention of future self-efficacy researchers, especially those in low-income countries.

Our review is not without limitations. It includes articles but not presentation papers, dissertations, and book chapters, thereby reducing the coverage of the existing research on engineering students' self-efficacy in higher education.

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SỰ TỰ TIN CỦA SINH VIÊN CHUYÊN NGÀNH KỸ THUẬT TRONG GIÁO DỤC ĐẠI HỌC: THỰC TRẠNG VÀ PHƯƠNG HƯỚNG NGHIÊN CỨU TRONG TƯƠNG LAI

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Tóm tắt: Bài báo này sử dụng phương pháp Systematic Quantitative Literature Review, đã đánh giá các nghiên cứu liên quan đến sự tự tin của sinh viên chuyên ngành kỹ thuật trong giáo dục đại học từ năm 2010 đến năm 2020 nhằm xem xét hiện trạng và đề xuất phương hướng nghiên cứu trong tương lai. Một trăm ba mươi lăm bài báo đã được chọn để phân tích các chủ đề nghiên cứu phổ biến nhất trên các quốc gia, các phương pháp nghiên cứu và mẫu nghiên cứu. Kết quả cho thấy các chủ đề được nghiên cứu nhiều nhất trên thế giới bao gồm: mối liên hệ giữa hiệu suất học tập và sự tự tin, sự tự tin và giới tính / chủng tộc, sự tự tin

của sinh viên chuyên ngành sư phạm kỹ thuật và bảo tồn, sự tự tin và tinh thần khởi nghiệp. Rất ít nghiên cứu xem xét hiệu quả của tính tự tin của sinh viên kỹ thuật trong việc học tiếng Anh, học trực tuyến hoặc E-learning. Phần lớn các nghiên cứu được được thực hiện ở Hoa Kỳ và các nước phát triển và trong một bối cảnh duy nhất (a single setting). Đa số nghiên cứu sử dụng Phương pháp định lượng. Không nhiều công trình sử dụng phương pháp định tính hoặc phương pháp nghiên cứu hỗn hợp. Sinh viên đại học là đối tượng được nghiên cứu nhiều nhất, tiếp theo là sinh viên đã tốt nghiệp và sinh viên sau đại học. Bài đánh giá này chỉ xem xét các bài báo đã xuất bản trên các tạp chí chứ không bao gồm các báo cáo trình bày, luận án và các chương sách.

Keywords: sinh viên chuyên ngành kỹ thuật, lòng tự tin, giáo dục đại học, đánh giá

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