

Igniting Active Engagement in Pre-Service Teachers in STEM Education: A Comprehensive Systematic Literature Review

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ABSTRACT

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Active engagement is a topic of research in instructional approaches within education. Research reveals that numerous benefits appear once students seem to be active and gain higher-order thinking skills, increase motivation and are engaged in their learning. Although there are numerous studies on active engagement in Science, Technology, Engineering and Mathematics (STEM) education, the effort to conduct a systematic review of this area of research has been complex due to the lack of review procedures, which presents a significant dispute for authors to clarify. Thus, a systematic literature review regarding active engagement in STEM education will be conducted in this research. Five key methodological steps led the review: research questions formulation, systematic search strategies depending, critical quality appraisal, as well as data extraction and analysis. Relying on the thematic analysis, four major themes were revealed: (1) critical thinking, (2) collaboration, (3) interaction, as well as (4) encouragement. Findings from the four themes further entail four relevant activities: lectorials, exploration, sharing knowledge, and assessment. According to the findings of the papers reviewed, getting pre-service teachers involved in active engagement activities leads to more comprehensive benefits on pre-service teachers' attitudes, problem-solving skills, and achievement in learning activities.

Contribution/Originality: This study is one of the few studies that have investigated and aims to perform a comprehensive SLR that focuses specifically on adopting active engagement in STEM education.

1. Introduction

Teachers are adjusting the method they teach in response to the possibilities of active engagement strategies, employing alternative teaching and learning methodologies, for instance, peer instruction, problem, and project-based learning, as well as the inverted classroom (Christie & de Graaff, 2017; Knobloch et al., 2018; Morais et al., 2021). These strategies generally aim to increase students' active engagement by encouraging them to do activities, participate actively, and reflect on their actions. The holy grail of education might be defined as student engagement. Likewise, Barlow and Brown (2020), Pöysä et al. (2019), and Struyf et al., (2019) have connected these phrases to favourable learning outcomes in and out of school. Engagement can lead to long-term participation in schooling.

It is essential for students to participate actively in science education through learning strategies, for instance, learnings by doing via experiential, inquiry, and project-based (Corrigan & Smith, 2020; Pöysä et al., 2019; Sinatra et al., 2015). Active participation in science education denotes students actively investing their energy in the learning processes within the classroom, consequently granting them a purposeful experience in connection with STEM-related educational activities (Chi & Wylie, 2014; Kim et al., 2020; Struyf et al., 2019). The active involvement of students in the learning process extends beyond constructivist learning methods, encompassing both psychological and behavioral engagement, for instance, involvement in educationally effective practices, higher-order thinking skills, and efforts made for the study (Almeda & Baker, 2020; Sari et al., 2020; Skinner et al., 2017). Higher-order thinking skills do not emerge naturally. Alternatively, they must be developed by engagement in educational classroom activities (Bickford et al., 2020; Suwarna & Rhodiatussolihah, 2020; Wahid et al., 2018). Active engagement refers to the extent to which students actively participate in educational activities with the aim of achieving high-quality learning outcomes (Almeda & Baker, 2020; Chi & Wylie, 2014; Sinatra et al., 2015). Students should demonstrate strong commitment and actively strive to enhance higher-order cognitive processes by engaging deeply in science activities (Baharin et al., 2018; Bickford et al., 2020).

It should also be highlighted that there is a limited comprehensive systematic literature review (SLR) of active engagement in STEM education research commenced at this moment. SLR is a formal method for locating and synthesising relevant studies while adhering to structured, transparent, and replicable processes throughout the procedure (Higgins et al., 2019). This study's SLR is built explicitly on integrative review analysis, which incorporates quantitative, qualitative, as well as mixed methodologies research. The discussion of active engagement in STEM education, especially towards pre-service teachers, has piqued the attention of academics all around the globe.

Even though there is a significant body of literature on active engagement in STEM education, there was a minimal attempt to examine this research in a systematic manner, recognise patterns, and generate prospective themes on the issue. Notably, the review methods, for instance, identification, screening, and eligibility, were not entirely handled. Conventional literature review practices possess several shortcomings in terms of transparency and bias. Most scholars prefer to write papers that support their study (Greyson et al., 2019; Mohamed Shaffril et al., 2020). Future researchers would find it challenging to imitate the study, justify the interpretations, or assess its depth with such a system in place.

Considering these research gaps, this study is one of the few studies that have investigated and aims to perform a comprehensive SLR that focuses specifically on adopting active engagement in STEM education. The scholars' empirical results may be supported by utilising this technique to highlight gaps and subsequent direct study in this area. The primary research question drove the authors as they progressed through the review: 'How do the previous studies implement an active engagement activity in their studies?'. Additionally, this research aims to discover appropriate active engagement activities in STEM education for teaching pre-service teachers to overcome challenges in an ever-changing society.

2. Literature Review

2.1. Active Engagement in STEM Education

STEM (Science, Technology, Engineering, and Mathematics) education plays a crucial role in preparing students for the demands of the modern world. It focuses on providing students with knowledge and skills necessary to succeed in an increasingly technology-driven world ([Silm et al., 2017](#); [Theobald et al., 2020](#)). Active engagement in STEM education is a powerful pedagogical approach that enhances student interest, motivation, and achievement in STEM subjects. Active engagement, characterised by student-centered and hands-on learning experiences, has been recognised as an effective pedagogical approach to enhance student interest, motivation, and achievement in STEM subjects ([Cook & Buck, 2017](#); [Schaal, 2010](#)).

Findings from various research shows many benefits of active engagement in STEM education such as increased student interest, improved learning outcomes and enhanced motivation ([Almeda & Baker, 2020](#); [Deák et al., 2021](#); [Prince et al., 2020](#)). Active engagement strategies promote a deeper understanding of STEM concepts, as students construct knowledge through hands-on experiences. This approach encourages critical thinking, problem-solving skills, and the application of knowledge in authentic contexts, leading to improved learning outcomes. Applying this strategy during teaching and learning will motivate students by providing them with opportunities to explore, discover, and take ownership of their learning ([Nagadeepa et al., 2021](#); [Saeed & Mohamedali, 2022](#)). Students develop a sense of ownership and investment by actively participating in learning, resulting in increased motivation and engagement.

Outcomes of active engagement in STEM education have been associated with increased retention rates and persistence in STEM fields. By fostering a positive learning experience and nurturing student interest, active engagement strategies contribute to reducing attrition rates in STEM disciplines. According to [Sandrone et al. \(2021\)](#), embracing active learning as the foundation of STEM education provides an opportunity to enhance student performance, surpassing traditional lectures. It also helps to reduce achievement disparities among underrepresented students and promotes equity and inclusivity. Active engagement approaches have shown promise in promoting diversity and inclusion in STEM education. By providing equitable access to hands-on experiences and collaborative learning environments, active engagement strategies can help bridge the gender and diversity gaps in STEM participation.

In summary, active engagement in STEM education offers students a wide range of benefits and outcomes. It enhances their STEM knowledge and skills, nurtures problem-solving abilities, fosters creativity and innovation, strengthens collaboration and

communication, boosts confidence and self-efficacy, prepares them for future careers, and promotes inclusivity and equity. By actively participating in STEM education, students are better prepared to face the challenges of the modern world and contribute to scientific and technological advancements.

Active engagement of pre-service teachers in STEM education is crucial for their professional development and for preparing them to effectively teach STEM subjects to students. By actively engaging pre-service teachers in STEM education through these strategies, they will develop a solid foundation in STEM subjects, gain practical teaching experience, and be better prepared to inspire and educate the next generation of STEM learners.

2.2. Active Engagement among Pre-service teachers

Active engagement of pre-service teachers in STEM education is crucial for their professional development and future success as educators. Implementing active engagement in pre-service teacher training is fundamental to enhancing learning and providing opportunities to practice and develop important teaching skills. For example, through role-playing activities or microteaching sessions, they can hone their instructional techniques, classroom management skills, and communication abilities. This hands-on experience better prepares them for real classroom situations. Besides that, active engagement strategy encourages pre-service teachers to think critically, analyse information, and solve problems. By engaging in discussions, debates, and case studies, they develop higher-order thinking skills essential for effective teaching. This strategy prepares them to tackle challenges they may encounter in their future classrooms. Actively participating in learning experiences allows pre-service teachers to gain confidence in their abilities. As they actively engage in discussions, practice teaching, and receive feedback, they become more comfortable in their role as educators. This confidence is essential for their professional growth and success as teachers.

According to research by [Topsakal et al. \(2022\)](#), it can be claimed that active engagement bridges the gap between theory and practice. Pre-service teachers get opportunities to apply the knowledge gained in their coursework to real-world situations. By engaging in simulations, field experiences, and internships, they develop a deeper understanding of how to translate educational theories into effective teaching practices.

In this context, it has been concluded that active engagement techniques align with student-centred learning approaches, which focus on individual student needs and active participation ([Calderón et al., 2020](#); [Maugh, 2018](#); [Rosicka, 2016](#)). By experiencing student-centered activities as pre-service teachers, they better understand the benefits of such approaches and are more likely to implement them in their future classrooms. Overall, implementing active engagement in pre-service teacher training fosters a more engaging and effective learning experience, equipping future educators with the necessary skills, knowledge, and confidence to become successful teachers.

3. Methodology

3.1. The Review Protocol- ROSES

The RepOrting standards for Systematic Evidence Syntheses (ROSES) review methodology were utilised to assist the current investigation. ROSES is a systematic review and mapping system in a non-medical field (Haddaway et al., 2018). ROSES is designed to encourage scholars to provide relevant information with appropriate detail. The scholars began their SLR relying on this review process by developing acceptable research questions for the review. The scholars next go into the systematic search strategy, which is characterised by three major sub-processes: identification, screening (exclusion and inclusion criteria), as well as eligibility. The scholars subsequently proceed to a quality assessment of the shortlisted papers. Correspondingly, they describe the technique employed to ensure the paper's quality is assessed. Ultimately, the scholars describe how the review's data was abstracted, as well as how the abstracted data was analysed and validated.

3.2. Research Questions Formulation

PICo was employed to develop the research question for this investigation. The term PICo, which stands for Population or Problem, Interest, and Context, assists authors in formulating an appropriate research question for the review process (Lockwood et al., 2015). The authors have incorporated three significant characteristics into the formulation, including pre-service teachers (Population), active engagement activities (Interest), and STEM education (Context). These formulations have then guided the authors to construct their main research questions: "How do the previous studies implement active engagement activities in STEM Education for teaching pre-service teachers?".

3.3. Systematic Searching Strategies

To find the pertinent papers, Mohamed Shaffril et al. (2020) offered three systematic identification, screening, and eligibility methods. Utilising these procedures, the authors could find and synthesise all the publications to perform a transparent and well-organised SLR.

3.3.1. Identification

The identification method entails looking for synonyms, similar phrases, and variations of the research's major keywords, including STEM education, active engagement, and pre-service elementary teachers. Its goal is to present the chosen database with greater possibilities for searching for additional pertinent documents for the review. According to Okoli (2015), the keywords are created depending on the research question. The identification procedure depends on keywords proposed by Scopus, keywords from past research, an online thesaurus, and keywords suggested by professionals. On Scopus databases, the authors supplemented the current keywords. They created a full search string (depending on field code functions, wild card, truncation, phrase searching, and the Boolean operator), as indicated in Table 1.

Owing to some advantages it holds, for instance, advanced searching functions, comprehensive (indexing over 5000 publishers), quality controls of the articles, as well as a multidisciplinary focus, which includes investigations connected to environmental management, this database can be a prominent database in an SLR (Gusenbauer & Haddaway, 2020; Martín-Martín et al., 2018). Web of Science, the second database, was chosen as a supplementary database. When applicable, the Boolean operator (OR, AND)

and phrase searching were utilised to mix terms, for instance, “science education”, “STEM Education”, “active engagement” and “actively engage”.

Table 1: Search string applied in the selected database.

Database	Search string
Scopus	TITLE-ABS-KEY (((“active engagement*” OR “active-engagement*” OR “actively engage*”) AND (“STEM education” OR “STEM” OR “STEM discipline*” OR “science education” OR “Science, Technology, Engineering and Mathematics”) AND (pre-service teacher*” OR “pre-service teacher*” OR “college teacher*” OR “training teacher*”)))
Web of Science	TS= ((“active engagement*” OR “active-engagement*” OR “actively engage*”) AND (“STEM education” OR “STEM” OR “STEM discipline*” OR “science education” OR “Science, Technology, Engineering and Mathematics” AND (pre-service teacher*” OR “pre-service teacher*” OR “college teacher*” OR “training teacher*”)))

Four additional sources were utilized as supplementary databases. The selected sources were ERIC, Science Direct, Google Scholar, and Mendeley. Access to these databases is necessary to acquire additional sources, including non-indexed journals and any articles that may be missing from the primary databases. In order to address the limitations highlighted by [Xiao and Watson \(2017\)](#), that argued no database is impeccable, and the findings of [Bates et al. \(2017\)](#), who concluded that the sensitivity of databases in retrieving articles based on keyword searches does not reach 100%, it becomes imperative to utilize supplementary databases.

In addition, [Haddaway et al. \(2018\)](#) recommended Google Scholar as an extra resource, citing its capacity to operate as a supplementary database in the systematic review process. Moreover, Google Scholar are chosen depending on several factors. Firstly, it provides massive results, as [Gusenbauer \(2019\)](#) determined in their analysis that this database has 389 million entries. Compared to discovery tools, [Orduna-Malea et al. \(2017\)](#) discovered that Google Scholar possesses 165 million accessible journals as well as articles. Apart from that, Google Scholar has proven to be outstanding in retrieving accessible scholarly materials, including renowned publishers ([Loan & Sheikh, 2018](#)). The procedure of searching these databases, yielded 974 papers.

3.3.2. Screening

The screening technique was the second step, in which publications were either included or omitted from the research (manually screened or using the database by the authors) depending on several criteria (see [Table 2](#)). Taking into account [Kraus et al. \(2020\)](#)’s idea of research field maturity, this study confined the screening procedure to publications issued between 2014 and 2020. The quantity of published research was adequate to do a representative review. Hence, this chronology was considered. Subsequently, the time period between 2014 to 2021 was chosen as one of the inclusion criteria. Considering empirical research publications include primary data, the authors chose to review them. To prevent any misunderstandings, only those submitted in English were accepted. Given the SLR goal was to promote active engagement in STEM education, one of the criteria was to include social science research papers. This was thought to boost the chances of obtaining more publications relating to active engagement strategies in STEM education. This method deleted 6 similar entries and rejected 721 entries that violated the inclusion criteria. Therefore, the residual 247

papers were employed in the third step of the procedure, which was determining eligibility.

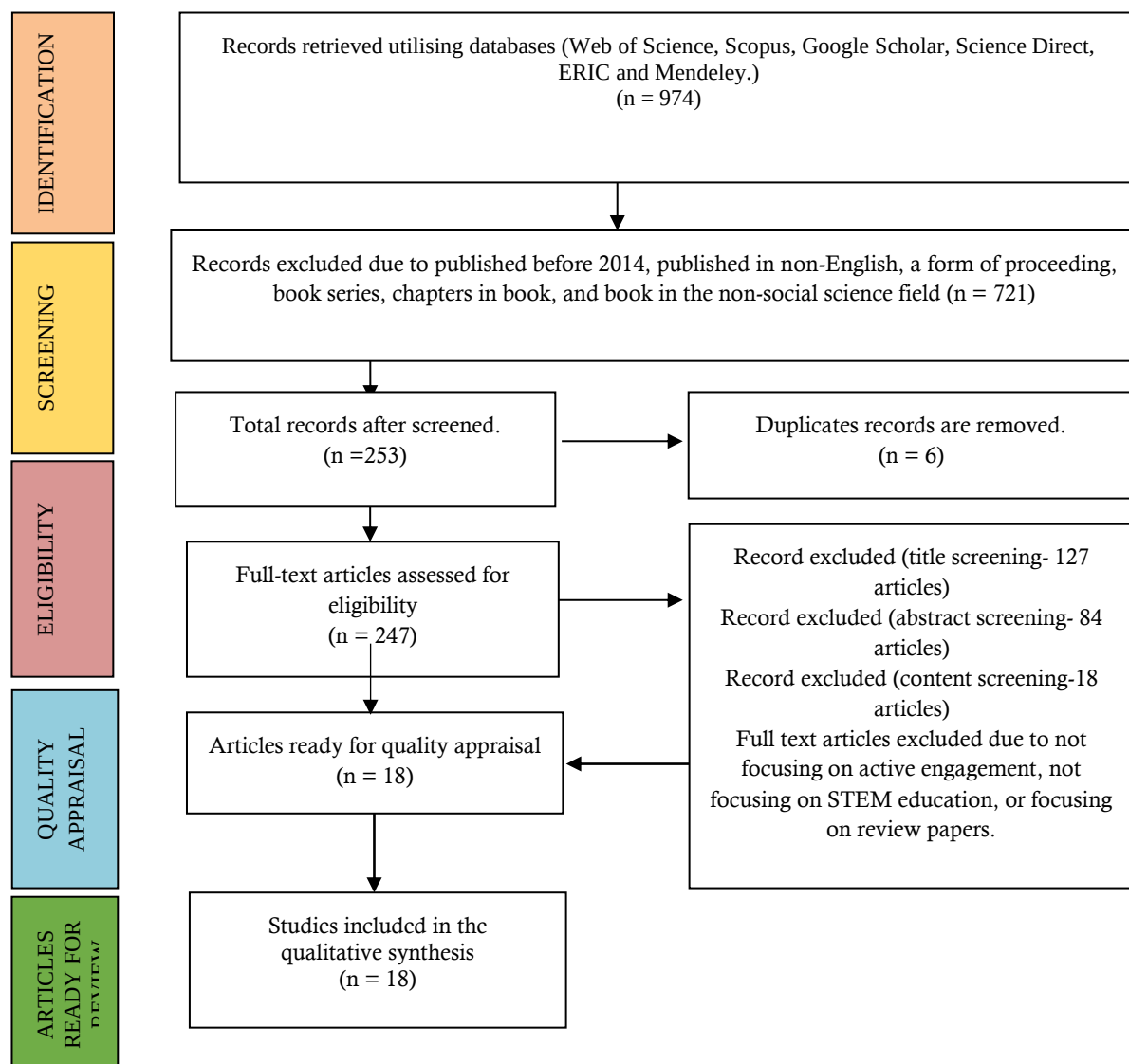
Table 2: Criteria for Inclusion And Exclusion

Criterion	Inclusion	Exclusion
Timeline	2014-2021	2013 and earlier
Type of Document	Empirical data articles	Conference proceeding, book, chapter in a book, review article
Language	English	Non-English
Subject area	Social Science	Other non-social science studies include geography, engineering, environmental science, public health, medical

3.3.3. Eligibility

The authors personally check the recovered papers during the eligibility phase to guarantee that every remaining article (following the screening procedure) meets the requirements.

Figure 1: Flow diagram of the searching strategies process



Note that this was performed by reading the paper titles as well as abstracts. Also, this procedure eliminated 229 publications that emphasised interactive and passive engagement rather than active engagement, focusing on non-STEM education focusing on review, not empirical data. The methodological portion is not well outlined and is presented as a book chapter. There were just 18 publications chosen in total (see [Figure 1](#)).

3.4. Quality Appraisal

The purpose of the quality appraisal stage was to guarantee that the analysis and methodology of the studies reviewed were done to the satisfaction of the researchers. The Mixed-Method Appraisal Tool (MMAT) introduced by [Hong et al. \(2018\)](#) was utilised for this. MMAT allows scholars to conduct a systematic mixed-methods review and assess five types of research: mixed-methods studies, quantitative descriptive studies, non-randomised studies, randomised controlled trials, and qualitative research ([Hong et al. 2018](#)). Prior to every study's quality evaluation, two screening steps were performed. The quality of the chosen papers was appraised utilising five primary criteria outlined in the research design. MMAT assisted in emphasising criteria, for instance, interpretation, analysis, data collection, the consistency between qualitative data sources, the sufficiency of qualitative data collection for addressing the research questions, and the suitability of the research questions to deliver sufficient data. This is to guarantee the chosen qualitative sources adhered to robust methodology and were subjected to stringent analysis.

The authors utilised the assessment criteria for their quantitative research design. The significance of the sampling technique was assessed based on its relevance to the research questions and the representativeness of the sample in relation to its population, the measurement suitability, as well as the analysis appropriateness done are among the factors utilised to evaluate it. In the meantime, MMAT assisted in delivering guidance pertaining to the rationale for utilising mixed-method to discuss research questions, the efficiency of distinct research designs to respond to the research questions, the integration of quantitative and qualitative, as well as the capacity to resolve differences and divergence between research designs in order to regulate the quality from analysis and methodological perspectives for mixed-method research designs.

The respective writer subsequently appraised the methodological and analytical rigour of each publication with the help of two co-authors. Each publication was thoroughly studied, with particular attention paid to the methodology section and the analyses performed. The authors scrutinised the publications utilising MMAT as a guide, looking for consistency in the sampling and analysis (for example, random sampling versus inferential analysis) as shown in the [Table 3](#). Note that each item was graded on five criteria, having three possibilities for displaying the results: "yes," "no," and "do not know/cannot tell." The papers were only considered for review if they met three criteria. All evaluation conclusions were made by consensus, and any disagreements were quickly resolved via discussion among the authors.

Table 3: The assessment utilised in the selected articles

Research Design	Assessment criteria
Qualitative	QA1: "Is the qualitative approach appropriate to answer the research question?" QA2: "Are the qualitative data collection methods adequate to address the research question?" QA3: "Are the findings adequately derived from the data?" QA4: "Is the interpretation of results sufficiently substantiated by data?" QA5: "Is there coherence between qualitative data sources, collection, analysis and interpretation?"
Quantitative (descriptive)	QA1: "Is the sampling strategy relevant to addressing the research question?" QA2: "Is the sample representative of the target population?" QA3: "Are the measurements appropriate?" QA4: "Is the risk of nonresponse bias low?" QA5: "Is statistical analysis appropriate to answer the research question?"
Quantitative (non-randomised):	QA1: "Are the participants representative of the target population?" QA2: "Are measurements appropriate regarding both the outcome and intervention (or exposure)?" QA3: "Are there complete outcome data?" QA4: "Are the confounders accounted for in the design and analysis?" QA5: "During the study period, is the intervention administered (or exposure occurred) as intended?"
Mixed Methods	QA1: "Is there an adequate rationale for using a mixed methods "design to address the research question?" QA2: "Are the different components of the study effectively integrated to answer the research question?" QA3: "Are the outputs of the integration of qualitative and quantitative components adequately interpreted?" QA4: "Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?" QA5: "Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?"

Source: [Hong et al. \(2018\)](#)

All authors concurred that all chosen publications fulfilled the minimal quality standard in terms of technique and analysis as a result of this procedure. Eight publications met all of the requirements, five publications achieved four or more of the criteria, and four more papers met three and above of the criteria, as shown in [Table 4](#).

Table 4: The quality assessment results

Study	Research Design	QA1	QA2	QA3	QA4	QA5	Number of criteria fulfilled	Inclusion in the review
Cakir (2013)	QN(DC)	/	X	/	X	/	3/5	/
O'Grady et al. (2014)	QN(DC)	/	/	/	X	/	4/5	/
Kim et al. (2015b)	MM	/	/	/	/	/	5/5	/
Tomas et al. (2015)	MM	/	/	/	/	/	5/5	/
Fogg-Rogers et al.	MM	X	/	/	/	/	4/5	/

(2016)								
Greene-Clemons	MM	/	X	X	/	/	3/5	/
(2016)								
Sahin-Taskin (2017)	QN(DC)	/	/	/	/	/	5/5	/
Avsec & Jagiello-	QN(DC)	/	/	/	/	/	5/5	/
Kowalczyk (2018)								
Li et al. (2018)	QN(DC)	/	/	/	/	/	5/5	/
Volet et al. (2019)	MM	/	X	X	/	/	3/5	/
Calderón et al. (2020)	MM	X	X	/	/	/	3/5	/
Jeong et al. (2020)	QN(DC)	/	/	/	/	/	5/5	/
Sarkadi et al. (2020)	QL	/	/	/	X	/	4/5	/
Kim et al. (2020)	QN(DC)	/	/	/	X	/	4/5	/
Ahshan (2021)	QN(DC)	/	/	/	/	/	5/5	/
Dearamae et al. (2021)	QL	/	/	/	/	/	5/5	/
Nagadeepa et al.	QN(DC)	/	/	/	X	/	4/5	/
(2021)								
Kilty et al. (2021)	QL	/	/	/	/	/	5/5	/

QN (DC) = Quantitative descriptive; QA = Quality assessment; QN (NR) = Quantitative non-randomised; QL = Qualitative; MX = Mixed-Method; C = Can't tell

3.5. Data Extraction and Analysis

Considering the review rely on a variety of research designs, the papers were thematically analysed, with qualitative synthesis being utilised to highlight the optimal strategies to merge the variations (Whittemore & Knafl, 2005). While there are other qualitative syntheses that might be utilised, the current study focused on the technique proposed by Flemming et al. (2019), where the study emphasised the flexibility of theme synthesis in synthesising data from various research designs. Thematic analysis is an analytical approach that aims to identify and uncover patterns or correlations of previous research via recognising any patterns or correlations in the data (Braun & Clarke, 2019). Thematic synthesis was done in this review following the procedures recommended by Kiger and Varpio (2020). The scholars initially became acquainted with the complete dataset through active and frequent readings. In addition, this technique gave the scholars a good overview of the raw data and laid the groundwork for the rest of the procedure. These processes throughout the thematic analysis using the Atlas.ti software.

The second step was to create the initial codes. The data was organised at a granular and detailed level by the authors. During this step, the scholars examined all of the papers that were chosen and retrieved any data that was relevant to the main study topic. The theme generation was the third step. The scholars utilised inductive coding frameworks to see whether there were any connections, similarities, or interests between the extracted and coded data. Note that the themes for the synthesis were derived from the coded data using an inductive coding approach. The produced themes were linked to the novel data and were representative of the full dataset (Braun & Clarke, 2019).

Six main themes were developed throughout the thematic analysis using the Atlas.ti software during this process. The authors then replicated the technique for each of the themes to discover any probable sub-themes, yielding 11 sub-themes. The created themes were then reviewed in the next step. The authors evaluated the primary themes and sub-themes applicability and chose to merge three key themes: creating, evaluating, and analysing, as one theme, termed higher-order thinking skills. The nine sub-themes were kept, while the primary themes were lowered to four. Two professionals in

qualitative synthesis as well as community development were subsequently provided with the sub-themes and themes and requested to verify them. Both professionals were questioned on the themes' relevance to the research questions. By employing this approach, all four themes remained consistent, namely: (1) critical thinking, (2) collaboration, (3) interaction, and (4) encouragement.

4. Result

4.1. The Selected Articles Background

From 18 articles, a total of three publications emphasised their research in the United States (Greene-Clemons, 2016; Kilty et al., 2021; Kim et al., 2015b), two in Australia (Tomas et al., 2015; Volet et al., 2019), Spain (Calderón et al., 2020; Jeong et al., 2020) and Turkey (Cakir, 2013; Sahin-Taskin, 2017). In the meantime, every research study also concentrated on India (Nagadeepa et al., 2021), Ireland (O'Grady et al., 2014), the United Kingdom (Fogg-Rogers et al., 2016), Slovenia (Avsec & Jagiello-Kowalczyk, 2018), China (Li et al., 2018), Indonesia (Sarkadi et al., 2020), South Korea (Kim et al., 2020), Oman (Ahshan, 2021) and Thailand (Dearamae et al., 2021) (refer Figure 2).

Figure 2: Countries where the selected studies were performed

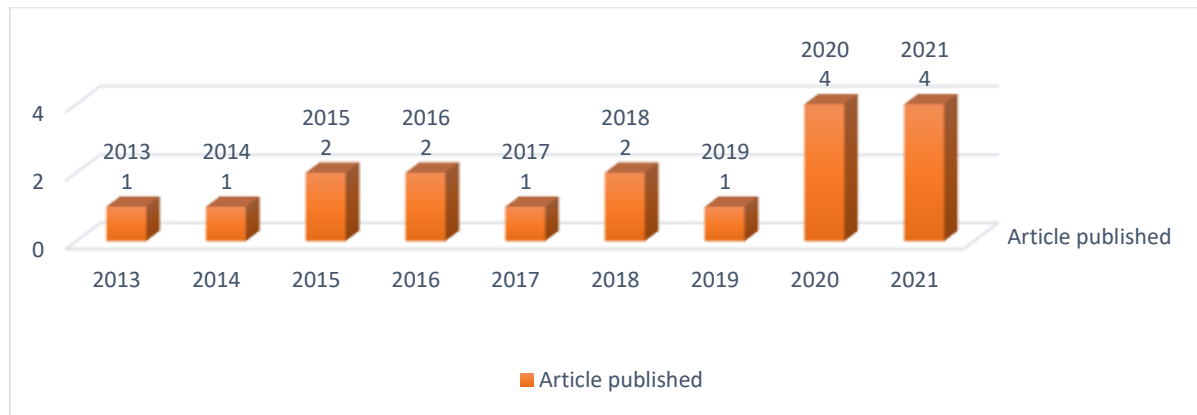


Nine researchers (Ahshan, 2021; Avsec & Jagiello-Kowalczyk, 2018; Cakir, 2013; Fokkens-Bruinsma & Canrinus, 2014; Jeong et al., 2020; Kim et al., 2020; Li et al., 2018; Nagadeepa et al., 2021; O'Grady et al., 2014; Robroo, 2019; Sahin-Taskin, 2017) utilised on quantitative analyses, whereas the other three studies (Dearamae et al., 2021; Kilty et al., 2021; Sarkadi et al., 2020) employed qualitative analyses. Another six articles worked on mixed-method approaches (Aydeniz & Bilican, 2018; Calderón et al., 2020; Fogg-Rogers et al., 2016; Greene-Clemons, 2016; Kim et al., 2015a; Tomas et al., 2015; Volet et al., 2019).

Concerning the year of publication, one paper was released in 2013 and 2014, respectively (Cakir, 2013; O'Grady et al., 2014), while two studies were published in 2015 (Kim et al., 2015a; Tomas et al., 2015), two articles were published in 2016 (Fogg-Rogers et al., 2016; Greene-Clemons, 2016) and one article in 2017 (Sahin-Taskin, 2017). Next, in 2018, two publications were released (Avsec & Jagiello-Kowalczyk, 2018; Li et al., 2018), one study was published in 2019 (Volet et al., 2019), four were published

in 2020 (Calderón et al., 2020; Jeong et al., 2020; Kim et al., 2020; Sarkadi et al., 2020), and four papers published in 2021 (Ahshan, 2021; Dearamae et al., 2021; Kilty et al., 2021; Nagadeepa et al., 2021) (see Figure 3).

Figure 3: Publication Years of selected studies



In addition, two publications were released in the Journal of Computers & Education (Cakir, 2013; Kim et al., 2015a), according to the review and three in the Journal of Education Sciences (Ahshan, 2021; Jeong et al., 2020; Kim et al., 2020). In the following journals, however, just one paper was published: Turkish Journal of Computer and Mathematics Education (Nagadeepa et al., 2021), European Journal of Teacher Education (O'Grady et al., 2014), Australian Journal of Teacher Education (Tomas et al., 2015), European Journal of Engineering Education (Fogg-Rogers et al., 2016), Journal for Multicultural Education (Greene-Clemons, 2016), Asia-Pacific Journal of Teacher Education (Sahin-Taskin, 2017), International Journal of Engineering Education (Avsec & Jagiello-Kowalczyk, 2018), Interactive Learning Environments (Li et al., 2018), Journal of Learning and Individual Differences (Volet et al., 2019), Journal of European Physical Education (Calderón et al., 2020), Universal Journal of Education Research (Sarkadi et al., 2020), Journal of Physics: Conference Series (Dearamae et al., 2021) and Journal of Technology and Science Education (Kilty et al., 2021). Since the publications were indexed in Scopus databases, they were all of the high quality. The majority fell into one of two categories: Quartile 1 or Quartile 2 (refer to Table 5).

Table 5: Selected journals as well as their ranking

Journal	Total number of selected articles	Indexed by Scopus	Scopus Quartile
Journal of Computers & Education	2	✓	Q1
International Journal of Educational Research	1	✓	Q1
European Journal of Teacher Education	1	✓	Q1
European Journal of Engineering Education	1	✓	Q1
Journal for Multicultural Education	1	✓	Q1
Asia-Pacific Journal of Teacher Education	1	✓	Q1
International Journal of Engineering Education	1	✓	Q1
Learning and Individual Differences	1	✓	Q1
European Physical Education	1	✓	Q1
Journal of Education Sciences	3	✓	Q2
Australian Journal of Teacher Education	1	✓	Q2
Journal of Technology and Science Education	1	✓	Q2

Turkish Journal of Computer and Mathematics Education	1	✓	Q3
Universal Journal of Education Research*	1	✓	Q4
Journal of Physics: Conference Series	1	✓	Q4

*Discontinued in Scopus as of 2020

4.2. Content-Analysis on Activities

4.2.1. The Themes

It is worth noting that certain attributes, sharing similar themes, contribute to the emergence of active engagement as identified through the analysis. Thematic analysis was carried out on 18 publications, culminating in the identification of four main themes: (1) critical skills, (2) collaboration, (3) interaction, and (4) encouragement. These four themes further produced eleven sub-themes. Four themes and eleven sub-themes arose from the outcomes, providing answers to the SLR's second research question, 'How do the previous studies have implemented an active engagement activity in STEM Education for teaching pre-service teachers?'.

While the majority of the papers primarily pertain to science education, the strategies examined can be adapted to suit other science classrooms, such as physics, by incorporating similar themes. Engaging in activities like problem creation, questioning, solution-finding, and problem-solving necessitates critical thinking on the part of students. They are required to communicate and collaborate with their peers in order to arrive at solutions for their inquiries. Motivation is crucial in student learning, especially critical with inquiry activities. Without student motivation, active engagement and deep inquiry will not actually arise. Students are keen to learn, interested in their findings, and prefer asking questions when they are encouraged.

The identification and categorization of themes from the selected articles are consolidated in Figure 4, Figure 5, Figure 6, and Figure 7 within the network diagram. In the next section, we will go through the background of the studies we have chosen.

Figure 4: Activities that shared a critical thinking

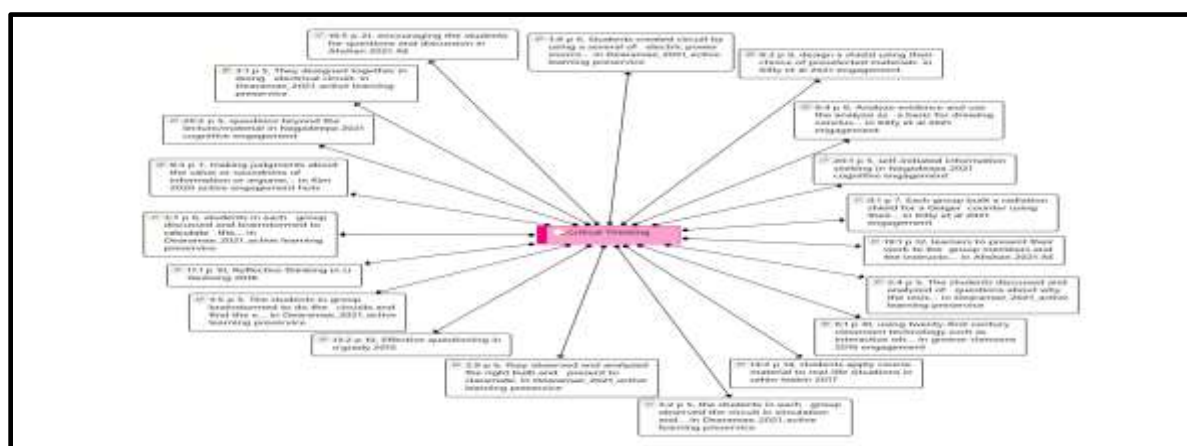


Figure 5: Activities that shared collaboration theme

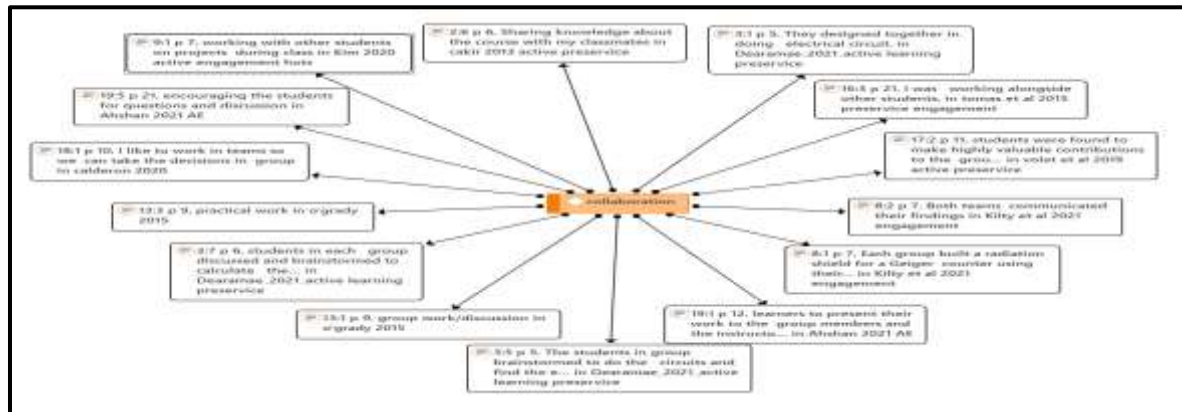


Figure 6: Activities that shared interaction theme

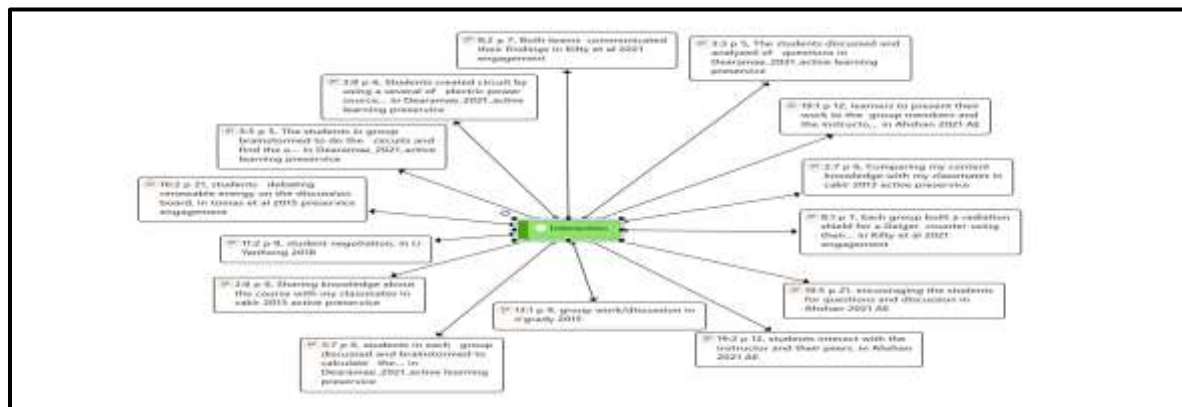
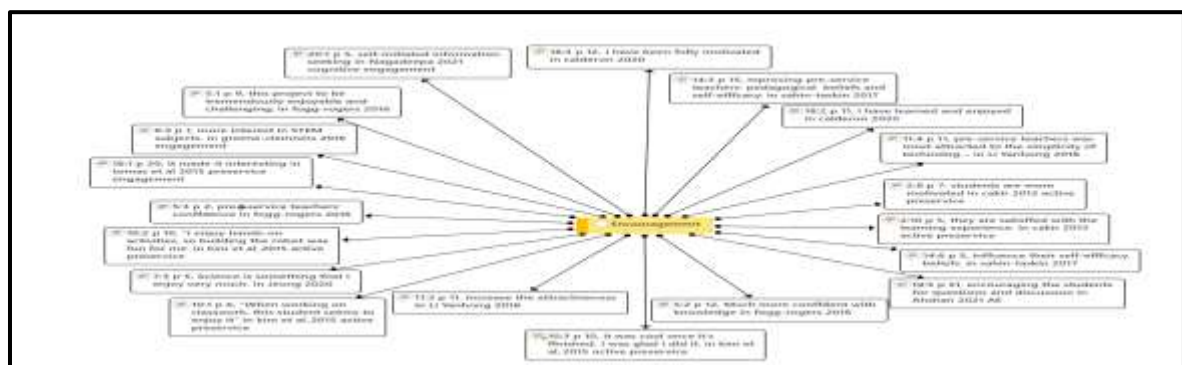


Figure 7: Activities that shared encouragement theme



a. Critical thinking

Students who are actively involved in their studies are active in learning. They process ideas and forge greater knowledge if they are fixing a problem, discussing an issue, or investigating a concept. In light of the significance of developing higher-order thinking skills, the teacher, as a crucial subject in learning, should plan learning activities that allow for the establishment of critical thinking abilities. Addressing analytical problems, creating questions and problems, motivating students to comprehend outside of the box, create ideas, identify solutions to their questions, and solve problems that require them to think critically are all examples of activities for creating critical thinking skills. This

theme was broken down into three sub-themes: analysis, evaluation and creation. The first sub-theme under critical thinking was analysing. Researchers suggest (Cakir, 2013; Dearamae et al., 2021; Kim et al., 2015a; Kim et al., 2020; Volet et al., 2019) that one way to develop pre-service teachers' critical thinking is by prompting them in learning science by utilising technology and engineering in STEM, such as discussing and analysing the questions about the difference of resistance in series and parallel circuits and then presenting to a classmate. While Jeong et al. (2020), Kilty et al. (2021), O'Grady et al. (2014), and Volet et al. (2019) revealed that some pre-service teachers develop their HOTS by analysing evidence and utilising the analysis as a foundation for concluding the problem-based learning project through integration of science and engineering parts.

The assessment was the subject of the second sub-theme. Students assess the worth of ideas, items, and materials (Dearamae et al., 2021; Faust & Paulson, 1998; Kim et al., 2020; Sahin-Taskin, 2017). Students are required to cognitively put all they have studied together in order to make enlightened and sound evaluations of the subject, for instance, judging the worth or soundness of information or arguments and brainstorming within the group to find the outcome (Dearamae et al., 2021; Jeong et al., 2020; Kim et al., 2020; O'Grady et al., 2014). Scholars (Fogg-Rogers et al., 2016; Li et al., 2018; Sahin-Taskin, 2017; Volet et al., 2019) stated that one of the key benefits of active learning and engagement strategies is that they assist students in building evaluative and critical capabilities that students could apply to real-life situations.

Some studies discovered that critical thinking could be enhanced by creating a model and using it to teach the information to others (Sahin-Taskin, 2017; Volet et al., 2019), such as creating a circuit by using several electric power sources, building or designing a shield utilising their judgement of preselected materials (Dearamae et al., 2021; Kilty et al., 2021). Students observe how individual reflection and collaborative interchange may result in stronger ideas and more original solutions to issues after a lot of experience exercising their creative muscles. Pre-service teachers' learning shifts from passively and unquestioningly ingesting material to being responsible for actively interacting with sources and views through these active learning activities (Avsec & Jagiello-Kowalczyk, 2018; Calderón et al., 2020; Greene-Clemons, 2016) and further it also fosters the enhancement of thinking skills and promotes students' creativity (Calderón et al., 2020; Kilty et al., 2021; Sarkadi et al., 2020; Tanak, 2020).

b. Collaboration

The first sub-theme is associated with sharing knowledge and engaging with a classmate while collaborating on a project. When students exchange ideas, it was observed that they learn to recognise leaps of logic, challenge presumptions, and build stronger arguments. Some research reported that by sharing knowledge about the course with a classmate, they would be able to work efficiently in teams, communicate their findings effectively and take a decision in a group (Cakir, 2013; Calderón et al., 2020; Kilty et al., 2021; Kim et al., 2015a; Kim et al., 2020; Tomas et al., 2015). Apart from that, Kim et al. (2020) and O'Grady et al. (2014) verified that students gain the skills necessary for collaboration in the workplace through breakout group work.

The second sub-theme is the concept of student involvement throughout project collaboration. Students can openly make precious contributions, freely listen to one another in group work, share ideas, brainstorm, discuss, and raise questions for which

no ready-made answers may exist (Dearamae et al., 2021; Greene-Clemons, 2016). Kilty et al. (2021) and Volet et al. (2019) also demonstrate social collaboration's importance in promoting active learning. Active learning pushes students out of their comfort zone by fostering an environment that encourages risk-taking. As students get more pleasant sharing their perspectives, justifying their discoveries, and building on one another's ideas, they will develop confidence, self-possession, and more engagement with peers. Furthermore, students' engagement and contribution in group work were demonstrated to be important, which Kim et al. (2020) showed may be enhanced by teachers facilitating students' communication.

c. Interaction

Under this theme, three sub-themes were produced: students-content interaction, students-students interaction, and students-instructor interaction. This theme is defined as the basic ways students can interact as it fostering active engagement in the process of teaching and learning (Ahshan, 2021; Diamantidaki & Kefalaki, 2019; Moore, 1989). Students can collaborate on interactive courses, projects, or simulations through Student-Content (SC) interactions. Students can collaborate with the instructor via synchronous online instruction or instructor-led discussion through student-instructor (SI) interactions. Through student-student (SS) interactions, students are able to collaborate with their peers through discussion forums, group activities, and laboratory experiments conducted in groups. The first theme is SC interaction. Students engage with course information by participating in project-based learning activities, discovering resources, and completing course assignments (Dearamae et al., 2021; Kilty et al., 2021; Volet et al., 2019). In order to retain active engagement and interest, O'Grady et al. (2014) and Sahin-Taskin (2017) suggested that course activities should be sequenced appropriately and varied in nature.

The next sub-theme is about SS interaction. Current research showed that students are more optimistic about the subject being studied where they can brainstorm and share knowledge about the course, and are more accepting of each other while communicating their findings when they work together cooperatively (Cakir, 2013; Dearamae et al., 2021; Kilty et al., 2021). This approach refers to Fogg-Rogers et al. (2016) and O'Grady et al. (2014), helping develop practical skills transferable to different classes and workplaces. Students gain a sense of positive empowerment and enablement in the classroom as a result of this technique, which allows them to express their critical points of view and assist other students with their tasks (Calderón et al., 2020; Kim et al., 2020; Li et al., 2018). Though SI interactions enable students to engage with the instructor through synchronous instruction or in an offline or online discussion led by the instructor (Cakir, 2013; Li et al., 2018; Volet et al., 2019). According to Ahshan (2021) and Tomas et al. (2015), this teaching style facilitates live contact between instructors and students, enhances communication efficiency, delivers immediate feedback via live discussion, and facilitates students to establish a social presence and decision-making efficacy.

Researchers have discovered a significant correlation between these interactions and learner satisfaction and learning results in both offline and online environments (Ahshan, 2021; Cakir, 2013; Dearamae et al., 2021; Kilty et al., 2021; Li et al., 2018; O'Grady et al., 2014; Tomas et al., 2015). Studies in Cakir (2013), Dearamae et al. (2021), Kilty et al. (2021), Li et al. (2018), and O'Grady et al. (2014) establish that SS interactions prompt the students to think they are real classmates in virtual settings, and referring to

Ahshan (2021), Cakir (2013), Kim et al. (2015a), Kim et al. (2020), Li et al. (2018), Tomas et al. (2015) and Volet et al. (2019), SI interactions provide students with the impression that their teachers are genuine individuals. Positive impacts on pursuing studies regularly, satisfaction with instructors and courses, learning performance, and students' motivation in teaching and learning are also revealed through SS and SI interactions. As a result, SS and SI interactions during teaching and learning can be said to assist in lessening isolation among peers as well as between instructors and learners. These interactions can promote active student engagement and help students study more effectively.

d. Encouragement

This main theme comprises three sub-themes: sharing experiences, fear-free classroom, and task interest (Table 6). Sharing experiences is the first sub-theme. Not all students will share their experiences; some will be preoccupied with books. However, when some students discuss their experiences related to the lesson, others will be motivated to participate actively. Some researchers (Fogg-Rogers et al., 2016; Greene-Clemons, 2016; Kim et al., 2020) claimed that students are much more confident and tremendously enjoyable when working on classwork together, even if the project is challenging. On the other hand, Ahshan (2021), Avsec and Jagiello-Kowalczyk (2018), Jeong et al. (2020), Sahin-Taskin (2017), and Tomas et al. (2015) discussed that pre-service teachers found active engagement strategies made the project more exciting and further encouraged the students for questions and discussion among them.

The second sub-theme is to ensure a fear-free classroom by encouraging comments and bringing excitement among the students in the classroom. Pre-service teachers enjoy hands-on activities and are motivated to complete the project for better results (Cakir, 2013; Calderón et al., 2020; Kim et al., 2015a; Li et al., 2018). Instil a sense of belonging in students while also recognising their cultural and social identities to provide various possibilities for constructive interactions with and among students (Ahshan, 2021; Nagadeepa et al., 2021; Volet et al., 2019). Students will be motivated and have more of a feeling of belonging when participating in activities promoting a mutual sense of purpose.

The next sub-theme is creating activities that enhance task interest and active engagement. Ahshan (2021) and Kim et al. (2015b) stated that in classrooms characterised by positive attitudes and emotions and high-interest levels in the tasks executed, students address higher motivation and perceptions of competence. Meanwhile, Calderón et al. (2020), Fogg-Rogers et al. (2016), and Tomas et al. (2015) explain that students who actively engage in tasks and activities linked to their interests find learning more relevant, enjoyable, and manageable to their life, and they act differently than those who do not. Integrating information into students' current interests further assists them in connecting their prior knowledge to academic learning and boosts their intrinsic motivation (Cakir, 2013; Greene-Clemons, 2016; Kim et al., 2020; Li et al., 2018; Volet et al., 2019).

Malmberg (2006) suggested at least three reasons why students with increased intrinsic drive will benefit teacher education. Firstly, as per Malmberg (2006), intrinsic motivation has a favourable influence on teaching strategies and job satisfaction. Secondly, students are highly responsive to learning when a genuinely motivated

teacher teaches them. Finally, as per [Malmberg \(2006\)](#), intrinsic motivation is necessary to commit to the trade, stay on the job, and access teacher studies.

Table 6: Themes-document related

Authors/Theme	Critical Thinking			Collaboration		Interaction			Encouragement		
	AS	ET	CT	SK	PI	SC	SS	SI	SE	FFC	TI
Cakir (2013)				/			/	/		/	/
O'Grady et al. (2014)	/	/		/		/	/				
Kim et al. (2015a)	/			/				/		/	/
Tomas et al. (2015)				/				/	/		/
Fogg-Rogers et al. (2016)		/					/		/		/
Greene-Clemons (2016)			/		/				/		/
Sahin-Taskin (2017)		/	/			/			/		
Avsec & Jagiello-Kowalczyk (2018)			/						/		
Li et al. (2018)		/					/	/		/	/
Volet et al. (2019)	/	/	/		/	/	/	/		/	/
Calderón et al. (2020)			/	/			/			/	/
Jeong et al. (2020)	/	/						/	/		/
Sarkadi et al. (2020)			/								
Kim et al. (2020)		/		/	/		/		/	/	
Ahshan (2021)								/	/	/	/
Dearamae et al. (2021)	/	/	/		/	/	/				
Nagadeepa et al. (2021)										/	
Kilty et al. (2021)	/		/	/	/	/	/				
Critical thinking	Collaboration			Interaction			Encouragement				
AS: Analysing	SK: Sharing			SS: Student-Student			SE: Share Experience				
ET: Evaluating	Knowledge			SC: Student-Content			FFC: Fear Free				
CT: Creating	PI: Plan Idea			SI: Student-Instructor			Classroom				
							TI: Task Interest				

5. Discussion

Active engagement is a crucial aspect that substantially affects students' learning and deepens understanding throughout online education. Upon reflection on the approaches, it is discovered that most papers address the same subject. Four themes of active engagement activities have been identified from the 18 selected papers based on the analysis. These are critical thinking, collaboration, interaction, and encouragement. Each theme is discussed in the papers listed in [Table 6](#).

The results from the preceding section highlight four activity themes, each of which encompasses four corresponding activities: lectorials, exploration, knowledge sharing, and assessment. Lectorial activities are the combination of lecture and tutorial to emphasise pre-service teachers' interactive nature. Lectorial activities are designed to change every 10 to 15 minutes, so each session includes typically two or three learning challenges mixed with some standard lecturing. The most important aspect of the lectorials design is the combination of traditional lecture segments with activities meant to actively involve students in their learning and give them sufficient time to digest information. Prior to the beginning of the course, pre-service teachers' perspectives, along with some readings and discussions facilitated by the lecturers, provide an

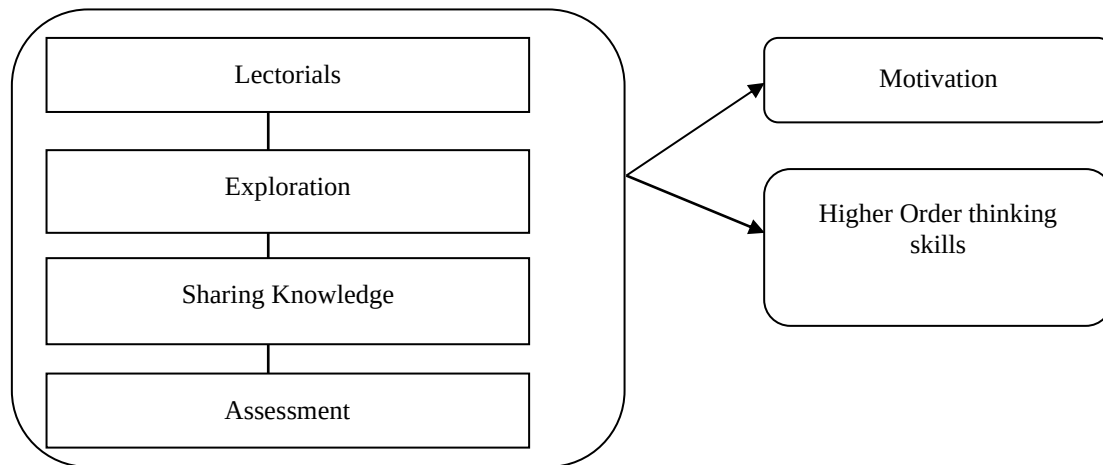
opportunity to have a big idea about the lesson through inquiry-based learning. Inquiry-based learning requires active engagement with the subject material and inquiry (Archer-Kuhn et al., 2020; Chen, 2021; Mamun et al., 2020). Sometimes the lecturer proffered his notions before assigning a related task that allowed students to think more deeply about what they had learned, and other times the learning activity was used as a prelude to the lecture-style delivery so that students had already begun thinking about the issue and were more responsive to the lesson content that followed. The lecturer will give an overview of the project as well as sources. Pre-service teachers construct new and prior knowledge during the inquiry process to produce innovative subjective realities. They will be encouraged to ask questions and exchange their ideas interactively, resulting in new fresh ideas and making their judgments explicit; they examine their perceptions and others' views and react accordingly and bring excitement among the students in the classroom (Boso et al., 2021; Wahid et al., 2018; Wrench & Paige, 2020).

Pre-service teachers benefit from a hands-on learning experience and active exploration throughout the exploration phase. Students develop one another's ideas and collaborate to design via exploration. The lecturer will ask questions about what pre-service teachers create during this stage and listen to their ideas. These interactions, which offer students active engagement in teaching and learning, are characterised as SC interactions, student-teacher interactions, and SS interactions (Ahshan, 2021; Diamantidaki & Kefalaki, 2019; Moore, 1989). Scholars have discovered a significant correlation between these interactions and learner satisfaction and learning results in both offline and online settings (Ahshan, 2021; Cakir, 2013; Dearamae et al., 2021; Kilty et al., 2021; Li et al., 2018; O'Grady et al., 2014; Tomas et al., 2015). Pre-service teachers enjoy hands-on activities and are motivated to complete the project for better results (Calderón et al., 2020; Kim et al., 2015a).

Next is the sharing knowledge phase, where pre-service teachers explain and elaborate the process to encourage them to investigate their concepts and exchange their designs with group members. Pre-service teachers can express their knowledge and reflect concepts during the explanation period. Apart from that, pre-service teachers will be motivated to clarify their thoughts to group members and come to a consensus throughout this session. In contrast, an elaboration session is an excellent opportunity for them to integrate learning objectives with real-world issues and clarify their ideas. Pre-service teachers will be motivated to exchange their designs with other groups and get feedback that develops a deeper and broader understanding (Chen, 2021; Rauch et al., 2022; Supiyati et al., 2022).

The assessment phase allows the lecturer to assess their pre-service teachers, as well as the pre-service teachers evaluate their own comprehension. Pre-service teachers answer questions regarding their design during the presentation session and explain their thinking. This phase will encourage pre-service teachers to work together to demonstrate what they can do. It has been proposed that pre-service teachers will be capable of clarifying, reorganising, elaborating, and updating their initial thought following passing over this cycle, as well as engaging with peers or the environment (Chen, 2021; Moon & Ke, 2020). Figure 8 below depicts the summary of the activities involved.

Figure 8: Summary of the activities involved.



6. Conclusion

Overall, the findings from the selected papers suggest that involving pre-service teachers in active engagement activities yields significant advantages in terms of their attitudes, problem-solving skills, and academic achievements in learning activities (Ahshan, 2021; Nagadeepa et al., 2021; Prince et al., 2020). Researchers explain that students who engage in activities and tasks related to their interests, detect learning as more available, highly enjoyable, and more pertinent to their lives (Calderón et al., 2020, Fogg-Rogers et al., 2016, Tomas et al., 2015). They execute greater than those without personalised content. Thus, if correct practical activities are implemented, the active engagement approach enhances pre-service teachers' motivation and thinking skills.

A systematic literature review identified and thoroughly examined 18 papers pertinent to the study's objectives. All papers share similar attributes and themes that can be implemented in active engagement activities. Through the analysis conducted, four themes of active engagement activities have been discerned: encouragement, interaction, collaboration, and critical thinking. These themes represent the fundamental conceptual elements that are advocated in 21st-century learning. Nevertheless, a more in-depth analysis of the activities is necessary to enhance the active engagement strategies for future research.

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Conflict of Interest

The authors reported no conflicts of interest for this work and declare that there is no potential conflict of interest with respect to the research, authorship, or publication of this article.

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