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ORIGINAL RESEARCH

Barriers and Facilitators of Robot-Assisted Education in Higher Education: A Systematic Mixed-Studies Review

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Abstract

Lack of motivation and enjoyment is a challenge that many students face. Due to the current coronavirus pandemic, many lessons are not being conducted face-to-face. However, the use of robots has been proven able to alleviate this challenge. This review explores the barriers and facilitators of robot-assisted education among higher education students. Ten databases were comprehensively searched for studies in English. Both published and unpublished studies were considered without a time limit. A systematic mixed-studies review was adopted and the mixed method appraisal tool was used to assess the methodological quality of the selected articles. The qualitative and quantitative findings were then synthesized via thematic and narrative syntheses, respectively. To integrate these two sets of findings, a result-based convergent synthesis was performed. A total of 28 studies covering 1689 higher education students across 14 countries were eventually used for the analysis. Most of these studies had average to high methodological quality. Two barrier themes were identified from these studies, namely, poor audio verbatim from the robots, and disruption and restrictions from software and hardware of the robot. Meanwhile, three themes related to facilitators were identified, namely, greater engagement in learning, facilitation in remote learning, and knowledge enhancement. The use of robot-assisted education has been proven to improve student learning in higher education. Robot-assisted education is an alternate educational technique that can be utilized to supplement and augment ongoing teaching arrangements. Future studies should examine a specific type of robot in a comparable learning environment.

Keywords Robots · Education · Higher education · Graduate education

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1 Introduction

Motivation to learn is critical for higher education (Yamashita et al., 2022). Lack of motivation is significantly related to high attrition rates in online higher education (Lucey, 2018). It is a significant predictor of leaving university without completing their degrees (Rump et al., 2017). Enjoyment is another critical component of learning (Hernik & Jaworska, 2018). Previous studies show that students consider their learning effective learning if enjoyment is present (Hernik & Jaworska, 2018; Okada & Sheehy, 2020). Lack of enjoyment in higher education is also a strong predictor of dropping out (Brubacher & Silinda, 2019). This issue is further exacerbated by the novel coronavirus (COVID-19) outbreak (Hong et al., 2017; Lizarondo et al., 2020), which forced students and teachers to switch to an online mode of learning (Almendingen et al., 2021; World Economic Forum, 2020; Wu, 2021). A recent study revealed that low motivation and enjoyment were associated with a low sense of belonging at university (Pedler et al., 2022). Therefore, improvement in motivation and enjoyment in their studies are essential elements, which can impact student achievement and contribute to student retention (Hernik & Jaworska, 2018; Yamashita et al., 2022).

Robots have the potential to become valuable tools in the educational field (Alnajjar et al., 2021). The evidence supported that robot is capable of assuming the roles of either a tutor or peer or serving as facilitators of learning activities (Anwar et al., 2019). Educational robotics (ER) is a popular method of teaching Science, Technology, Engineering, and Mathematics (STEM) subjects to students in grades K-12 through university (Souza et al., 2018; Zhong & Xia, 2020). This innovative educational method has showed valuable for learning by offering activities that are both enjoyable and functional (Afari & Khine, 2017; Alnajjar et al., 2021). Together with an attractive environment, ER can pique the interest and curiosity of students (Anwar et al., 2019). ER also provides students with a considerable learning edge by promoting their learning interest and motivation (Alnajjar et al., 2021). Given that students are usually drawn to tactile user interfaces and physical qualities, robot-assisted education can effectively motivate them to stay engaged in their learning activities.

Meanwhile, telepresence robots are valuable tools for facilitating remote learning (Lei et al., 2022). In education, videoconferencing has become a popular instrument that supports remote learning, especially during the COVID-19 pandemic as teachers and students transition from face-to-face lessons to online ones (Almendingen et al., 2021; World Economic Forum, 2020; Wu, 2021). A telepresence robot not only allows videoconferencing but also provides maneuverability and control over a remote camera (Jakonen & Jauni, 2021). A remote student can operate the robot from a distance to interact with people, objects and, environmental structures in the class (Lei et al., 2022).

However, students face external and internal barriers in their learning (Roslan & Halim, 2021). External barriers are beyond the control of individuals, such as their health, whereas internal barriers tend to be associated with personal attitudes (Lucas, 2020). Learners face many barriers that, when left unsolved, may lead to dropouts (Bozkurt & Akbulut, 2019). Therefore, the classroom experience of these learners should be improved to stimulate their personal growth and reflection (Wood et al., 2022). Facilitators of learning are defined as those factors that promote or enhance learning (Handrianto et al., 2021; Wood et al., 2022). These facilitators help individuals modify their habits and motivate them to overcome barriers (Handrianto et al., 2021). Hence, understanding the barriers and facilitators in learning is key to implementing changes in robot-assisted education.

A systematic mixed-studies review is particularly advantageous for a wide and encompassing research problem because this approach uses various types of data to provide a more thorough and in-depth understanding of the topic at hand by presenting other viewpoints (i.e., stories and numbers) (Hong et al., 2017). Any piece of literature can provide evidence to aid in the exploration, contextualization, generalization, or explanation of findings from other types of literature (Hong et al., 2017; Lizarondo et al., 2020; Pluye & Hong, 2014). With its breadth, a systematic mixed-studies review provides richer and more useful knowledge and insightful conclusions (Hong et al., 2017; Lizarondo et al., 2020). Robot-assisted education generally has numerous components, and mono-method reviews are less appropriate than systematic mixed-method ones in examining how these components relate and interact with one another (Heyvaert et al., 2016). As a result, these syntheses have a greater chance of influencing practice, policy, and future research.

Benitti (2012) reviewed the usage of ER in elementary, middle, and high schools and emphasized the potential contribution of robotics as an educational tool. Zhong and Xia (2020) investigated the use of robotics for teaching mathematics and identified four themes, namely, human–robot interaction, connections between mathematics and real life, pedagogical suggestions, and facility conditions. Both studies also highlighted the promising future use of ER in education. Spolaôr and Benitti (2017) quantitatively assessed the application of robots as auxillary tools in tertiary instituitions and analyzed their potential benefits in concept learning and skills improvement. Anwar et al. (2019) reviewed the use of educational robots in promoting the learning of K-12 students and identified five themes, namely, general effectiveness of ER, learning and transfer skills, creativity and motivation, diversity and broadening participation, and teachers' professional development. They suggested that ER has the potential to support those students showing no immediate interest in science and technology. Meanwhile, Papadopoulos et al. (2020) examined the use of socially assistive robots (SARs) in pre-tertiary education and found that utilizing SARs benefits the attitudes of young children.

However, none of the above systematic reviews confirm the barriers and facilitators of robot-assisted education. A mixed-studies systematic review is particularly useful in closing this gap given that this approach considers both quantitative and qualitative evidence, thereby complimenting their respective strengths and weaknesses and resulting in a more complete review (Hong et al., 2017; Tariq & Woodman, 2013). By integrating quantitative and qualitative evidence, associated findings can be corroborated, hence improving the present understanding of the topic at hand (Almalki, 2016; Hong et al., 2017; Tariq & Woodman, 2013). Given the shortcoming in the existing literature, the current mixed-studies review aims to explore the barriers and facilitators of robot-assisted education in higher education. Hence, the following research questions (RQs) are formulated to address the objective of the present review:

RQ1: What are the barriers of robot-assisted education in higher education?
RQ2: What are the facilitators of robot-assisted education in higher education?

2 Methods

This mixed-studies review was registered with the Open Science Framework registries (https://osf.io/5e9k6). The findings of this review were obtained using both qualitative and quantitative approaches, which allow for a well-rounded analysis through integration (Hong et al., 2017; Tariq & Woodman, 2013). Pertinent findings were combined to synthesize more substantive evidence (Almalki, 2016; Hong et al., 2017; Tariq & Woodman, 2013) to obtain an in-depth understanding of the barriers and facilitators of learning among higher education students. Results were presented following the Preferred Reporting Items for Systematic Review and Meta Analyses (PRISMA) guidelines (Page et al., 2021). The PRISMA checklist can be found in Appendix A.

2.1 Eligibility Criteria

This review focuses on higher education students of any level and on the barriers and facilitators of robot-assisted education in higher education. The articles were selected following a strict eligibility criterion based on the Setting, Perspective, Intervention, Comparison, and Evaluation (SPICE) framework to ensure an efficient identification of evidence and relevant studies (Booth, 2006). The full SPICE framework and eligibility criteria can be found in Appendix B and C. Mixed-methods, quantitative, and qualitative studies were included in the review. The selected articles comprised both published and unpublished studies that were exclusively reported in English and were published in any given year to ensure the comprehensiveness of the review and to maximize the selection of articles.

2.2 Search Strategy

A three-phase search strategy was applied. First, an initial search of PubMed was carried out by the first reviewer using index terms and keywords. The text words of the retrieved studies matching the inclusion criteria were then analyzed to generate a list of keywords and index terms for a comprehensive search. After deriving the related keywords and index terms, the Boolean operators "AND" and "OR" were used to combine the search terms. An experienced librarian was consulted to facilitate the development of an extensive search strategy. Using the developed search strategy, another comprehensive search was carried out across all 10 databases, namely, PubMed, Excerpta Medica DataBASE, Cumulative Index of Nursing and Allied Health Literature, IEEE Technology Xplore, Cochrane Library, Scopus, Web of Science, Education Resources Information Center, ProQuest, and Psychological Information Database from inception to December 31, 2021. The reference lists of the included articles were examined to identify additional studies. The full search strategy can be found in Appendix D.

To enhance the quality of the database search, the Peer Review of Electronic Search Strategies (PRESS) was utilized. Specifically, the requestor (person requesting the peer review) keyed in the information in the updated PRESS 2015 Guideline Assessment Form at the "primary" search strategy. The completed form was then sent to the reviewer to evaluate the search strategy using the PRESS 2015 Evidence-Based Checklist. As no major revision was advised, a second PRESS peer review of the revised strategy was not carried out. All records from the databases were collated using the EndNote 20 software, and the duplicates were removed (The EndNote Team, 2013). Several eligibility criteria were employed in the first phase of screening for titles and abstracts. The full texts of the remaining articles were then retrieved and thoroughly reviewed.

2.3 Methodological Quality Assessment

The Mixed Methods Appraisal Tool (MMAT) version 2018 was used to critically appraise all included articles. The MMAT can be found in Appendix E. Each selected article was appraised for their (1) study design, (2) evaluation of study selection bias, (3) sample size, (4) data collection methods, (5) intervention integrity, and (6) analysis. Methodological ratings of good (75–100%), fair (50–74%), and low (0–49%) were then assigned to each study after the appraisal. Methodological quality was not considered in the study selection to increase the rigour of the synthesis by allowing the consolidation of all available evidence.

2.4 Data Extraction

Qualitative data were extracted from the qualitative studies and from the qualitative sections of the selected mixed-methods studies. The same approach was also used to extract quantitative data. All data extraction work was performed using the modified extraction tool adapted from the Joanna Briggs Institute Mixed Methods Data Extraction Form, which follows a convergent integrated approach (Lizarondo et al., 2020). This data extraction form can be found in Appendix F. The extracted data included type of methodology, objective of the study, characteristics and settings of the participants, sample size, comparators (if any), measure of outcomes, results (quantitative studies), themes (qualitative studies), and barriers and facilitators of robot-assisted education. To ensure its validity and reliability, the data extraction tool was initially piloted on six of the included studies. Two reviewers (HSC and LTT) independently carried out the selection, data extraction, and quality assessment processes. Any discrepancy was resolved through mutual discussion and consultation with a third reviewer (YL). When necessary, the authors of the original included studies were contacted to clarify doubts or to ask for additional information.

2.5 Data Synthesis and Integration

The quantitative and qualitative syntheses were carried out individually followed by an integration of the pertinent findings in this mixed-studies review, which used a results-based convergent synthesis approach (Hong et al., 2017). Given that this review included a large number of articles, the qualitative findings were analyzed via thematic synthesis, which is useful for processing large datasets and producing clear and ordered results (Booth, 2006; King, 2004). The thematic synthesis was performed in three stages, namely, (1) line-by-line text coding, (2) development of descriptive themes, and (3) generation of analytical themes. The initial inductive codes were generated via line-by-line coding (Thomas & Harden, 2008) before they were compared, categorized, and grouped into subcategories based on their commonalities. Descriptive themes were then generated. The reviewers compared these descriptive themes against the textual data to derive analytical themes. The emerging themes were finalized via a discussion among the reviewers. The quantitative findings were not subjected to a meta-analysis given the differences in the approaches adopted by the selected studies. Therefore, to address any potential heterogeneity, a narrative synthesis was performed to provide a systematic summary of the selected papers. This approach strictly followed the framework of Popay et al. (2006). The outcomes of both syntheses were then compared to integrate the qualitative and quantitative findings.

3 Results

3.1 Study Selection

A total of 3603 articles were obtained. After removing the duplicates, 2065 articles were selected for analysis based on their titles and abstracts. Among these articles, 158 were retrieved for full-text screening, of which 28 articles (Abe et al., 2018; Aroca et al., 2013; Banaeian & Gilanlioglu, 2021; Corsby & Bryant, 2020; Cruz-Martín et al., 2012; Donnermann et al., 2020, 2021; Gleason & Greenhow, 2017; Gomez-de-Gabriel et al., 2011; Guo et al., 2014; Gyebi et al., 2017; Ibrahim et al., 2020; Kurniawan et al., 2018; Li et al., 2016; Lister et al., 2018; Molloy et al., 2016; Rosenberg-Kima et al., 2020; Sampsel et al., 2011; Scott et al., 2020; Shaw et al., 2018; Shimaya et al., 2021; Suárez-Gómez & Pérez-Holguín, 2020; Sun et al., 2017; Uzun, 2020; Ververi et al., 2020; Wang et al., 2021; Winkelmann & Eberman, 2020; Wong et al., 2021) matched the inclusion criteria and were eventually retained for this study. Figure 1 illustrates the PRISMA flow diagram.

3.2 Study Characteristics

Among the 28 selected articles, 8 had a mixed-methods design, 5 were qualitative, and 15 were quantitative. The majority of these studies were conducted in the US and Europe. All of them reported outcomes related to the barriers and facilitators of robot-assisted education. The qualitative studies mostly adopted focus groups and interviews, whereas the quantitative studies used surveys and questionnaires. Table 1 presents the characteristics of the selected articles.

3.3 Methodological Quality of the Selected Studies

The methodological quality of each study design was assessed using MMAT. The majority of these articles had average to high methodological quality. A total of 10 studies had high methodological quality, 14 studies had average methodological quality, and all other studies had low methodological quality. Some qualitative studies did not provide clear descriptions of their data collection and interpretation processes, and many failed to answer the specifics of their research questions. Most of the quantitative studies used outcome-specific measurement tools but failed to describe their sampling approaches in detail. Therefore, the researchers could not confirm whether the samples of these studies were reflective of their intended population. The randomized controlled trials (RCT) did not describe their randomization processes. The majority of the mixed-methods studies used both quantitative and qualitative approaches to answer their research questions but provided limited information about the quality of both approaches. The quality assessment of each study is described in Table 2.

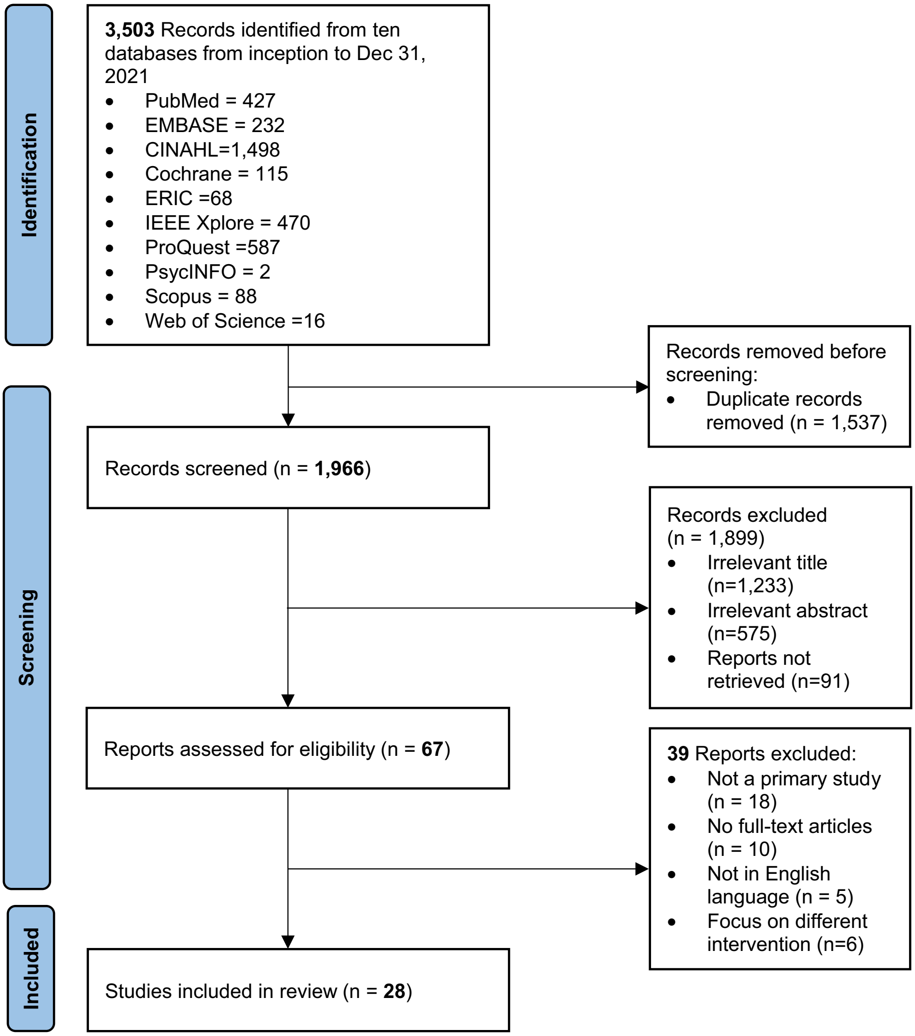

Fig. 1 PRISMA flow diagram

3.4 Qualitative Syntheses

Qualitative findings were organized into barriers and facilitators of learning. The barrier subthemes are (1) unclear verbatim verbal audio from the robot and (2) distraction from the robot gestures and appearance. Meanwhile, the facilitator subthemes are (1) enhancement of curiosity and interest, (2) increased motivation of learning, and (3) provide remote learning. Table 3 describes the qualitative syntheses in detail.

Table 1 Characteristics of 28 selected articles in mixed-studies review

Author (Year)	Country	Design	Population (sample size)	Type of robot (Brand)	Educational role	Data Collection
Abe et al. (2018)	Japan	Qualitative design	Dental student ($n = 10$)	Humanoid robot (SIMROID)	Assessment	Questionnaire
Aroca et al. (2013)	Brazil	Mixed-methods	Science and engineering students ($n = 204$)	Educational robot (Cellbot)	Demonstration	Survey
Banaeian and Gilanlioglu (2021)	Northern Cyprus	Mixed-methods	Freshman students of English language ($n = 65$)	Social robot (NAO robot)	Tutor	Interview Questionnaire
Corsby and Bryant (2020)	Wales	Qualitative design	Doctoral students ($n = 6$)	Telepresence robot (Double robotics)	Supervision	Focused group interview
Cruz-Martín et al. (2012)	Spain	Mixed-methods	Computer Science Engineering and Telecommunications Engineering (66)	Educational robot (LEGO Mindstorms)	Demonstration	Questionnaires
Donnermann et al. (2020)	Germany	Qualitative design	Digital media students (28)	Social robot (Pepper robot)	Tutor	Interview Questionnaires
Donnermann et al. (2021)	Germany	Mixed-methods	Digital media students (80)	Social robot (Reethi robot)	Tutor	Questionnaire
Gomez-de-Gabriel et al. (2011)	Spain	Survey	Students in Masters Engineering	Educational robot (LEGO Mindstorms)	Demonstration	Questionnaires
Gleason and Greenhow (2017)	US	Qualitative design	Doctoral students ($n = 11$)	Telepresence robot (Kubi robot & Double robot)	Peer	Focus group discussion Written reflection
Guo et al. (2014)	US	Case study	Mechanical, electrical, chemical, computer and biomedical engineering students ($n = 15$)	Capsule robot (Webot stimulator)	Demonstration	Project report Survey
Gyebi et al. (2017)	Ghana	Quasi-experimental	Undergraduate computer science education (166)	Educational robot (Thymio II)	Demonstration	Survey Scores of workshop activities Final examination
Ibrahim et al. (2020)	Malaysia	RCT	Undergraduate engineering students ($n = 205$)	Educational robot (Arduino Uno)	Demonstration	Questionnaires Pre and post mid-semester and final examination

Table 1 (continued)

Author (Year)	Country	Design	Population (sample size)	Type of robot (Brand)	Educational role	Data Collection
Kurniawan et al. (2018)	Singapore	RCT	First-year undergraduates ($n=100$)	Educational robot (Thymio)	Demonstration	Survey questionnaires
Li et al. (2016)	US	RCT	Undergraduate Communication ($n=40$)	Social robot (NAO robot)	Tutor	Questionnaire
Lister et al. (2018)	US	Mixed-methods	Pre-licensure nursing students ($n=73$)	Telepresence robot (Double robotics)	Assessment	Survey
Rosenberg-Kima et al. (2020)	Israel	Mixed-methods	Course students in Human Computer Interaction ($n=36$)	Social robot (NAO robot)	Tutor	Questionnaire
Molloy et al. (2016)	US	Survey	Pre-licensure ($n=48$) and nurse practioner students ($n=5$)	Telepresence robot	Supervision	Survey
Sampsel et al. (2011)	US	Qualitative design	Nursing students ($n=48$)	Telepresence robot (InTouch RP-7 robot system)	Supervision	Survey
Scott et al. (2020)	US	Mixed-methods	Nursing, medical and pharmacy students ($n=29$)	Telepresence robot	Supervision	Survey
Shaw et al. (2018)	US	Mixed-methods	Nursing students ($n=84$)	Telepresence robot (Double robotics)	Supervision	Questionnaire
Shimaya et al. (2021)	Japan	Quasi-experimental	University students ($n=62$)	Humanoid robot (CommU)	Peer	Questionnaire
Suárez-Gómez and Pérez-Holguín (2020)	US	Survey	Engineering graduate students ($n=18$)	Educational robot (LEGO Mindstorms)	Demonstration	Survey
Sun et al. (2017)	Japan	RCT	Students ($n=22$)	Humanoid robot (Aldebaran Robotics)	Teaching	Questionnaire
Uzun (2020)	Turkey	Qualitative design	ICT teachers' graduate level course ($n=6$)	Educational robot (Arduino based robotic kit)	Demonstration	Semi-structured interview

Table 1 (continued)

Author (Year)	Country	Design	Population (sample size)	Type of robot (Brand)	Educational role	Data Collection
Ververi et al. (2020)	Greece	Survey	First year chemistry students ($n = 49$)	Educational robot (Edison robot V2.0)	Demonstration	Questionnaire
Wang et al. (2021)	US	Survey	Undergraduates and graduates from computer science and information technology	Collaborative robot (Franka Emika Panda)	Assessment	Survey
Winkelmann and Eberman (2020)	US	Single cohort	Second year masters athletic training students ($n = 55$)	Telepresence robot (Double robotics)	Supervision	Questionnaire
Wong et al. (2021)	US	Mixed-methods	Second year pharmacy and nursing students ($n = 120$)	Telepresence robot	Supervision	Pre and post reflection Survey

n Number of sample; *RCT* randomized controlled trial; *US* United States

Table 2 Summary of quality assessment

Author (Year)	Criteria from the Mixed Methods Appraisal Tool																											Rating*/%
	S1	S2	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	3.4	3.5	4.1	4.2	4.3	4.4	4.5	5.1	5.2	5.3	5.4	5.5	
Aroca et al. (2013)	×	✓	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	85.7
Aroca et al. (2013)	×	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	✓	✓	✓	×	57.1
Banaeian and Gilanlioglu (2021)	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	✓	✓	✓	✓	100
Corsby and Bryant (2020)	×	✓	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	85.7
Cruz-Martín et al. (2012)	×	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	✓	✓	✓	?	57.1
Donnermann et al. (2020)	✓	✓	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						100
Donnermann et al. (2021)	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	✓	✓	✓	×	71.4
Gomez-de-Gabriel et al. (2011)	×	✓	-	-	-	-	-	-	-	-	-	-	✓	✓	✓	?	✓	-	-	-	-	-	-	-	-	-	-	71.4
Gleason and Greenhow (2017)	✓	✓	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100
Guo et al. (2014)	×	✓	-	-	-	-	-	-	-	-	-	-	?	?	✓	?	✓	-	-	-	-	-	-	-	-	-	-	42.9
Gyebi et al. (2017)	✓	✓	-	-	-	-	-	-	-	-	-	-	?	✓	✓	?	✓	-	-	-	-	-	-	-	-	-	-	71.4
Ibrahim et al. (2020)	✓	✓	-	-	-	-	-	-	-	-	-	-	?	✓	?	?	✓	-	-	-	-	-	-	-	-	-	-	57.1
Kurniawan et al. (2018)	✓	✓	-	-	-	-	-	×	✓	✓	?	×	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	57.1
Li et al. (2016)	✓	✓	-	-	-	-	-	-	-	-	-	-	?	✓	✓	?	✓	-	-	-	-	-	-	-	-	-	-	71.4
Lister et al. (2018)	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	✓	✓	✓	×	71.4
Rosenberg-Kima et al. (2020)	✓	✓	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100
Molloy et al. (2016)	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	?	?	×	?	✓	-	-	-	-	-	42.9
Sampsel et al. (2011)	✓	✓	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100
Scott et al. (2020)	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	?	×	×	?	?	28.6
Shaw et al. (2018)	×	✓	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	85.7
Shimaya et al. (2021)	✓	✓	-	-	-	-	-	-	-	-	-	-	?	✓	?	✓	✓	-	-	-	-	-	-	-	-	-	-	71.4
Suárez-Gómez and Pérez-Holguín (2020)	✓	✓	-	-	-	-	-	-	-	-	-	-	?	?	✓	?	✓	-	-	-	-	-	-	-	-	-	-	57.1
Sun et al. (2017)	✓	✓	-	-	-	-	-	?	×	✓	?	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	57.1
Uzun (2020)	✓	✓	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100
Ververi et al. (2020)	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	?	?	✓	?	✓	-	-	-	-	-	57.1
Wang et al. (2021)	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	?	?	✓	?	✓	-	-	-	-	-	57.1
Winkelmann and Eberman (2020)	✓	✓	-	-	-	-	-	-	-	-	-	-	✓	✓	✓	?	✓	-	-	-	-	-	-	-	-	-	-	85.7
Wong et al. (2021)	✓	✓	-	-	-	-	-	-	-	-	-	-	×	✓	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	85.7

3.4.1 Barriers From Qualitative Results

BANAEIAN and Gilanlioglu (2021) highlighted the importance of having advanced listening skills to comprehend the robot. In the same vein, Rosenberg-Kima et al. (2020) stated that the robot did not have a clear voice. Gleason and Greenhow (2017), Sampsel et al. (2011), and Wong et al. (2021) argued that the robot used a poor audio technology that should be improved. Donnermann et al. (2021) reported that the robot makes loud and distractive sounds. Similarly, Corsby and Bryant (2020) stated that the movement of the robot could disrupt the class. Gleason and Greenhow (2017) and Banaeian and Gilanlioglu (2021) found that instead of focusing on the class, the students were paying attention to the robot.

Table 3 Data analysis for qualitative studies for barriers and facilitators of robot-assisted education

Author (Year)	Quotations	Themes from studies (related to barriers and facilitators)	Barriers	Facilitators
Aroca et al. (2013)	"this should be released more broadly because it is very interesting and essential for undergraduate students." "concept of robotics should be added in undergraduate courses, given that the topic causes great curiosity and interest."	Robotics as a facilitator of learning	Absent	Enhancement of curiosity and interest
Banaeian and Gilanlioglu (2021)	"I know just one thing will be improving the robot ability to hear, receive sound because sometimes it has problems, I mean voice recognition" "Only thing that I had stress about was the sound, because when I went to the robot and I asked something, it couldn't hear me well, and teacher said 'Speak louder.' but I couldn't as required, I am shy" "In order to acquire some knowledge from that robot you have to know English like very well. Some sentences or the listening skill must be some advanced. I mean if you are advanced in listening skill you won't have any problem with it."	Technical drawback of the robot	Unclear verbal verbatim from the robot	Absent
	"It was motivating because it was a robot like something that every people haven't seen around the world"	Robotics as a facilitator of learning	Absent	Increase motivation of learning
	It was distractive after a while, I couldn't get used to the robot; my attention was on the robot itself rather than English, maybe if I get used to the robot in the future I may benefit, but at the moment I didn't benefit that much	Disruptive functions of the robot	Distraction from robot's gestures and appearance	Absent

Table 3 (continued)

Author (Year)	Quotations	Themes from studies (related to barriers and facilitators)	Barriers	Facilitators
Corsby and Bryant (2020)	"I really like the fact I can move with the screen. It gives me some power as a learner and makes me feel like I am in the room. That is important when compared to just being on a screen, like you are on Skype. However, the movement can be awkward and difficult to see where you are going. I got it wrong a few times." "I really liked that the technology allowed me to be in the class without actually being there. It took me a while to comprehend that I was actually involved in this class and I wasn't just watching, it wasn't a webcast for example, I was actually a part of the room and I was contributing."	Robotics as a facilitator of learning	Absent	Providing remote learning
	"I think remembering to set the robot up, charge it and support it is important. It would be disastrous to engage for half an hour and then the battery go flat. In terms of the set-up and planning, it was fairly straight forward, but I did need to accommodate that. I tend to prepare and up-load my slides before the session anyway."	Technical barriers of robots for learning	Technical difficulties of the robot	Absent

Table 3 (continued)

Author (Year)	Quotations	Themes from studies (related to barriers and facilitators)	Barriers	Facilitators
	"I felt like I didn't want to interrupt the class by moving the robot. It might be distracting. You don't want someone to be speaking and then a robot turns to their face. Calvin (a tutor) was very specific to direct questions towards me. That actually helped because Graham started to do that as well. So, Callum started explaining something then it went to Graham and he actually started quizzing me on something. It meant I could engage, but I was reliant on Calvin and Graham to initiate that discussion."	Disruptive factors of the robot	Distraction from robot's gestures and appearance	Absent
Cruz-Martín et al. (2012)	"My main reason was to get the extra grade, and the curiosity I felt about seeing embedded systems and particularly the LEGO Mindstorms."	Robotics as a facilitator of learning	Absent	Enhancement of curiosity and interest
Donnermann et al. (2021)	"The loud noise when Reeti was blinking was a bit annoying and distracting."	Disruptive factor of the robot	Distraction from robot's gestures and appearance	Absent
Gleason and Greenhow (2017)	"as a distance learner to feel closer"	Robotics as a facilitator of learning	Absent	Providing remote learning
	"The audio was one disadvantage"	Technical barriers of robots for learning	Unclear verbal verbatim from the robot	Absent
	"so focused on figuring out technology… that I was less focused"	Robot leads to loss of focus in the classroom	Distraction from robot's gestures and appearance	Absent
Rosenberg-Kima et al. (2020)	"voice not clear enough"	Technical barriers of robots for learning	Unclear verbal verbatim from the robot	Absent

Table 3 (continued)

Author (Year)	Quotations	Themes from studies (related to barriers and facilitators)	Barriers	Facilitators
Sampsel et al. (2011)	"Need to improve the audio communication of the robot"	Technical barriers of robots for learning	Unclear verbal verbatim from the robot	Absent
Scott et al. (2020)	"It was better than getting a phone call because I could see what was happening with my eyes and [I could] visualize teamwork." "helped me to be better prepared and confident in talking and working with a team of other disciplines."	Robotics as a facilitator of learning	Absent	Providing remote learning
Shaw et al. (2018)	"[The robot] was helpful from the provider perspective, requiring us to ask the right questions when we can't do an assessment ourselves."	Robotics as a facilitator of learning	Absent	Providing remote learning
Uzun (2020)	"I think my motivation through robotics increased after the course. I just came to learn at the beginning of the course. My motivation increased after making a product that we can use in real life"	Robotics as a facilitator of learning	Absent	Increase motivation of learning
Wong et al. (2021)	"Audio technology was poor, it cut out frequently."	Technical barriers of robots for learning	Unclear verbal verbatim from the robot	Absent

3.4.2 Facilitators from Qualitative Results

AROCA et al. (2013) and Cruz-Martín et al. (2012) reported that the use of robotics in class increased the curiosity and interest of students in learning. Banaeian and Gilanlioglu (2021) identified novelty as a factor that motivated the students to learn. Similarly, Uzun (2020) found that the motivation levels of students increased after attending classes involving robots. In Corsby and Bryant (2020), Gleason and Greenhow (2017), and Shaw et al. (2018), the participants appreciated how the use of robots allowed remote learning. Coincidentally, all these studies utilized telepresence robots.

3.5 Quantitative Syntheses

The quantitative findings were organized into barriers and facilitators of learning. The barrier categories include (1) limitations in robot software development, (2) poor audio function of the robot impedes communication, (3) restricted assessment capability, (4) poor video ability of the robot, and (5) robot gestures can be a distraction. Meanwhile, the facilitator subthemes include (1) more interesting to learn, (2) higher learning motivation, (3) boost in confidence, (4) enhanced understanding of the lesson, (5) feel comfortable for learning, and (6) robot is realistic. Table 4 presents the quantitative syntheses in detail.

3.5.1 Barriers From Quantitative Results

According to Kurniawan et al. (2018), the most commonly reported issues in using robots in the class are related to debugging errors in the software, which they perceived to be a waste of time that could have been spent in delivering the lesson. Banaeian and Gilanlioglu (2021) reported that the robot could not comprehend the participants accurately if their pronunciation was incorrect or if their voice was not loud enough. Therefore, the audio ability of the robot should be improved to enhance its communication with the students. Similarly, Shaw et al. (2018) reported that more than half of the participants were facing problems with the volume and voice connection of the robot. The same problems were reported by Lister et al. (2018), who reported that the interactions between the participants and the robot were interrupted by technical problems. In Lister et al. (2018), a significant number of the participants felt that their assessment capabilities were limited by the use of the telepresence robot. The same problems were reported in Shaw et al. (2018). Shaw et al. (2018) observed a video response delay with the robot. Similarly, Winkelmann and Eberman (2020) reported that the robot had no video.

According to Donnermann et al. (2020), the students thought that the hands and arm movements of the robot were disturbing.

3.5.2 Facilitators From Quantitative Results

AROCA et al. (2013) reported that using the robot increased the interest of the participants in their learning. Kurniawan et al. (2018) and Suárez-Gómez and Pérez-Holguín (2020) obtained similar findings. Donnermann et al. (2020) found that students were more interested to learn with robot-supported tutoring, whereas Rosenberg-Kima et al. (2020) discovered that the students found the robot interesting. However, Shimaya et al.

(2021) reported no significance increase in the learning interest of the students with or without the robot. Cruz-Martín et al. (2012) reported that using the robot increased the learning motivation of students in all their courses except for one. Similarly, Donnermann et al. (2021), Guo et al. (2014), and Gyebi et al. (2017) reported that students experienced a higher learning motivation due to the presence of the robot. Winkelmann and Eberman (2020) reported that the overall confidence score of the participants improved after the use of robots. Molloy et al. (2016) and Shaw et al. (2018) found that the students became more confident to meet their lesson objectives. Similar results were reported by Lister et al. (2018).

Cruz-Martín et al. (2012) and Ibrahim et al. (2020) observed an improvement in the examination scores of the students, hence suggesting that the use of the robot helped the students better understand their lesson content. Gomez-de-Gabriel et al. (2011) and Li et al. (2016) obtained similar results. Guo et al. (2014) and Suárez-Gómez and Pérez-Holguín (2020) reported that the understanding level of the students increased after the intervention with the robot. Donnermann et al. (2020) stated that the robot provided step-by-step explanations to help the students better understand their lesson. However, Shimaya et al. (2021) and Sun et al. (2017) reported no differences in the participants' understanding of the lesson with or without the robot. The majority of the participants in Banaeian and Gilanlioglu (2021) reported that using the robot was comfortable for learning. This finding is in line with those of Donnermann et al. (2020), where the participants felt more relaxed and less pressured in the presence of the robot. Sun et al. (2017) reported similar findings. The majority of the participants in Scott et al. (2020) agreed that the scenario with the robot was realistic. This finding was in line with those of Lister et al. (2018).

3.6 Integration of Results

Five themes emerged from the integration of the quantitative and qualitative syntheses and were organized into barriers and facilitators using a results-based convergent synthesis approach. The barrier subthemes include (1) poor audio verbatim from the robot and (2) disruption and restrictions in the software and hardware of the robot, whereas the facilitator subthemes include (1) greater engagement in learning, (2) facilitation of remote learning, and (3) knowledge enhancement. Figure 2 illustrates the process of integration, whereas Table 5 shows the integration of the quantitative and qualitative studies.

4 Discussion

This mixed-studies review compiled both the quantitative and qualitative findings from 28 studies involving 1689 higher education students across 14 countries. The methodological quality of selected studies was high (35.7%), average (50%) and low (14.3%) using MMAT. A results-based convergent synthesis approach was used to identify five themes related to two barriers and three facilitators of robot-assisted education in higher education.

Table 4 Data analysis for quantitative studies for barriers and facilitators of robot-assisted education

Author (Year)	Result	Interpretation (related to barriers and facilitators)	Barriers	Facilitators
Aroca et al. (2013)	83% said they thought it would be more interesting to learn several topics using a CellBot to apply the theory they had learned (for the population, the average estimate is in the interval from 76 to 89% with a confidence level of 95%) 58.5% of the students said that they would prefer to own their own robots, this number increased to 71% in the post-survey, showing that using a CellBot increased the overall student interest (for the population, the average estimate is in the interval from 64 to 77% with a confidence level of 95%) 23% of these students said that they would not spend any money on an educational robot or on a robotic kit	Interesting to use the robot for learning	Absent	More interesting to learn
Banaeian and Gilanlioglu (2021)	65.5% of the students agreed that the robot is comfortable for learning ($n = 19$) Although 76% of the participants stated that the robot could hear them, interviewees reported that this feature had some limitations and problems. Sometimes the robot could not understand students since their voice was not loud enough or their pronunciation was not correct	Students felt comfortable to learn with the robot Robot unable to comprehend the students' speech	Poor audio function of robot impedes communication	Feel comfortable for learning

Table 4 (continued)

Author (Year)	Result	Interpretation (related to barriers and facilitators)	Barriers	Facilitators
Cruz-Martín et al. (2012)	The mean of the students' motivation from Real-Time Systems course increase from 2.65 to 2.94 The mean of the students' motivation from Control and Data Acquisition course increased from 3.50 to 4.20 The mean of the students' motivation from Control System Laboratory decreased from 3.53 to 3.36 The mean score of the exam for the students from Real-Time Systems course increased from 0.85 to 1.30 The mean score of the exam for the students from Control and Data Acquisition course increased from 1.60 to 1.86 The mean score of the exam for the students from Control System Laboratory from 0.51 to 0.56	Robot motivates the students Robot helped the students to learn the content better	Absent	Higher learning motivation Enhance understanding of content

Table 4 (continued)

Author (Year)	Result	Interpretation (related to barriers and facilitators)	Barriers	Facilitators
Donnermann et al. (2020)	The robot-supported tutoring was rated best with a mean of M = 6.32 (SD = 0.76), showing that the students were interested in learning with the robotic tutor Some students particularly emphasized the step-by- step explanations of the exercises ($n = 4$) 25% of the participants ($n = 7$) praised that the robot gave a comprehensive answer if their answer was wrong Half of the students ($n = 13$) saw advantages in the robotic tutor as well, as it was mentioned that while learning with the robot they felt less pressured, more relaxed, are not afraid or ashamed of making mistakes and that they valued the opportunity to let the robot repeat the explanation over and over again 36% of the students ($n = 10$) perceived that hand and arm movement of the robot as too much and disturbing 21% of the participants ($n = 6$) noted that the gestures of the robot were negative aspects	Interesting to use the robot for learning Robot helped the students to learn the content better Gesture by the robot can be distracting	Robot gesture can be a distraction	More interesting to learn Enhance understanding of lesson Feel comfortable for learning
Donnermann et al. (2021)	Attitude towards the topic was positively correlated with intrinsic motivation ($r = 0.38$, $p = 0.001$)	Robot motivates the students	Absent	Higher learning motivation

Table 4 (continued)

Author (Year)	Result	Interpretation (related to barriers and facilitators)	Barriers	Facilitators
Gomez-de-Gabriel et al. (2011)	The mean value of acquired competencies for participants in summer school raised from 1.65 to 3.63 The mean value of acquired competencies for participants in Mobile robotics raised from 2.41 to 3.76	Robot helped the students to learn the content better	Absent	Enhance understanding of lesson
Guo et al. (2014)	Student understanding before and after the case study was improved from an average 2.15 to 3.78 The average level of the students' motivation is 3.87	Robot helped the students to learn the content better Robot motivates the students	Absent	Enhance understanding of lesson Higher learning motivation
Gyebi et al. (2017)	There is significant difference between the robot-based activity and paper-based activity. Mean $\pm$ SD of the motivation score for the robot-based activity was 4.2 ± 0.8 compared to the paper-based activity of 3.7 ± 0.8, with p-value of 0.00 and $r = 0.38$	Robot motivates the students	Absent	Higher learning motivation

Table 4 (continued)

Author (Year)	Result	Interpretation (related to barriers and facilitators)	Barriers	Facilitators
Ibrahim et al. (2020)	There is statisticallysignificant difference in mid-semester exam marks for the experimental group (Mean: 48.443, SD: 18.848) and control group (Mean: 34.077, SD: 14.334) with p-value < 0.0001. This finding suggests a statistically significant improvement of final exam marks to the experimental group compared with the control group The median marks for the control and experimental groups are 11.0 and 21.0, respectively, showing the improvement of final exam marks for about 10 marks. This positive finding shows students' academic achievement increased by about 15% with the use of a robotic-based project	Robot helped the students to learn the content better	Absent	Enhance understanding of lesson

Table 4 (continued)

Author (Year)	Result	Interpretation (related to barriers and facilitators)	Barriers	Facilitators
Kurniawan et al. (2018)	Students agreed that the physical robot led to more participation in the workshop lesson and tasks compared to the stimulator. The average score of the students in the physical robot group was 4.37 while the average score of the students in the stimulator group was 3.57 Students agreed that the physical robot led to more interest in learning in programming. The average score of the students in the physical robot group was 4.52 while the average score of the students in the stimulator was 3.57 12 students (25%) complained about hardware problems. Highest reported issues were related to debugging errors in the software of the robot and time to debug the robot during the intervention. 9 students (18%) complained about debugging issues and 4 students (8%) complained about time wasted to debugging	Robots led to more participation in class Interesting to use the robot for learning Debugging error in software of the robot Time wasted on solving software related issue	Limitations in robot software development	Promote participation in class More interesting to learn
Li et al. (2016)	Participants' knowledge recall (% questions correct) was higher with the non-virtual (Mean = 0.893, SD = 0.069) rather than virtual version (Mean = 0.800, SD = 0.154) C of the human instructor, but lower with the non-virtual (Mean = 0.82, SD = 0.108) rather than virtual version (Mean = 0.886, SD = 0.102) of the robot agent	Robot helped the students to learn the content better	Absent	Enhance understanding of lesson

Table 4 (continued)

Author (Year)	Result	Interpretation (related to barriers and facilitators)	Barriers	Facilitators
Lister et al. (2018)	22 (41.5%) found that their assessment capabilities were limited by the use of telepresence, 19 (35.8%) reported that the use of this technology made the interaction feel impersonal, 9 (17.0%) found technical problems interfered with the interaction Realistic (mean = 4.1 ± 0.75) Teaching methods as helpful and effective (mean = 4.19 ± 0.72) improvement in students' confidence in their ability to communicate via video technology ($p < 0.001$) They found this method of instruction a suitable way to learn (mean = 4.29 ± 0.74) The students responded most favourably (mean = 4.47 ± 0.60) to the survey statement "I enjoyed how my instructor taught the simulation." 9 (17.0%) found technical problems interfered with the interaction Students felt more confident to assess the wound after the intervention. Pre-intervention (Mean = 3.29, SD = 0.95) and post intervention (Mean = 3.88, SD = 0.71), with p-value < 0.001 Students felt more confident in their ability to perform wound care and dressing care after the intervention. Pre-intervention (Mean = 3.11, SD = 1.10), and post intervention (Mean = 3.78, SD = 0.84), with p-value < 0.001	Limitation of assessment capabilities Impersonal interaction Poor audio verbatim Robot give the students more confidence in their learning Interesting to use the robot for learning Robot provides realistic learning experience	Poor audio function of robot impedes communication Restricted assessment ability	Boost in confidence More interesting to learn Boost in confidence Robot is realistic

Table 4 (continued)

Author (Year)	Result	Interpretation (related to barriers and facilitators)	Barriers	Facilitators
Rosenberg-Kima et al. (2020)	Students reported that the activity with the robot was pleasant and interesting and the overall mean for the attitudes towards the robot facilitation scale was 3.55 (±.62)	Interesting to use the robot for learning	Absent	More interesting to learn
Molloy et al. (2016)	Pre-licensure students (Mean = 4.39, SD = 0.72) and nurse practioner students (Mean = 4.4, SD = 0.55) agreed that the simulation provided them a variety of learning materials and activities to promote their learning of the class objectives Pre-licensure students (Mean = 3.72, SD = 1.08) and nurse practioner students (Mean = 4.4, SD = 0.55) agreed that they are confident to master the content presented	Robot give the students more confidence in their learning Robot helped the students to learn the content better	Absent	Boost in confidence
Scott et al. (2020)	93% rated agree or strongly agree that the scenario resembled a real-life situation	Robot provides realistic learning experience	Absent	Robot is realistic

Table 4 (continued)

Author (Year)	Result	Interpretation (related to barriers and facilitators)	Barriers	Facilitators
Shaw et al. (2018)	More than half of prelicensure students (53.6%) reported difficulty with volume, voice connection, and video response delays 20% reported "see" or physically "assess" the manikin as challenges Pre-licensure students (Mean = 3.72, SD = 1.08) and nurse practioner students (Mean = 4.4, SD = 0.55) agreed that they are confident to master the content presented Pre-licensure students (Mean = 4.39, SD = 0.72) and nurse practioner students (Mean = 4.4, SD = 0.55) agreed that the simulation provided them a variety of learning materials and activities to promote their learning of the class objectives	Poor volume and audio connection Delay in video response Limitations in physical assessment Robot helped the students to learn the content better Robot give the students more confidence in their learning	Poor audio function of robot impedes communication Restricted assessment ability Poor video ability of the robot	Boost in confidence
Shimaya et al. (2021)	Students were less hesitant to ask questions with the robot in class (Mean = 5.3, SD = 1.5) than without the robot in class (Mean = 5.8, SD = 1.2), p-value = 0.038 Students participated more actively in class with the robot (Mean = 4.8, SD = 1.3) than without the robot (Mean = 4.2, SD = 1.6) There was no significant difference in the interest towards the class with (Mean = 6.0, SD = 1.2) or without the robot(Mean = 6.0, SD = 0.90), *p*-value = 1.000 There is no significant difference in the understanding of the lecture with (Mean = 5.7, SD = 1.2) or without the robot (Mean = 5.8, SD = 1.0), *p*-value = 0.690	Robots led to more participation in class Not interesting to use the robot for learning Robot did not help the students to learn the content better	Absent	Promote participation in class More interesting to learn Enhance understanding of lesson

Table 4 (continued)

Author (Year)	Result	Interpretation (related to barriers and facilitators)	Barriers	Facilitators
Suárez-Gómez and Pérez-Holguín (2020)	With a 5-point Likert scale, the students evaluated its own comprehension level of these concepts before (3.85) and after (4.78) the use of LEGO Mindstorms Majority of the students agreed that the use of Educational Robotics helps to improve programming skills by developing application exercises. With a 5-point Likert scale, the average response was 4.57 Majority of the students agreed that the use of Educational Robotics helps to increase interest in learning processes by developing practical exercises. With a 5-point Likert scale, the average response was 4.71	Robot helped the students to learn the content better Interesting to use the robot for learning	Absent	Enhance understanding of lesson More interesting to learn

Table 4 (continued)

Author (Year)	Result	Interpretation (related to barriers and facilitators)	Barriers	Facilitators
Sun et al. (2017)	No significant difference with regard to understood the game well after the description of the game rules, the mean score for both two conditions was under 3 (Without Robot TA: Mean = 2.94, SD = 0.94; With Robot TA: Mean = 2.89, SD = 1.18). Therefore, either teacher or Robot TA did not ensure students understand the game well when the rules of the game were explained and described only in verbal Statistical analysis also showed that the mean score of Q7 (I was worried whether I could do it well after learning the rules of game.) was significantly higher for Without Robot TA condition (Mean = 4.00, SD = 1.24) when compared to With Robot TA condition (Mean = 3.33, SD = 0.77). This suggested that the use of Robot TA allowed the students to achieve the task with less anxiety and more confidence Statistical analysis shows that the students were more relaxed with the Robot TA (Mean = 3.44, SD = 1.04) than without the Robot TA (Mean = 3.28, SD = 1.07)	Robot did not help the students to learn the content better Students felt comfortable to learn with the robot	Absent	Enhance understanding of lesson Feel comfortable for learning

Table 4 (continued)

Author (Year)	Result	Interpretation (related to barriers and facilitators)	Barriers	Facilitators
Ververi et al. (2020)	49% indicated that are interested to a great extent in new IT methodologies Statistical analysis shows that students are interested in new information technologies (Mean = 4.2, SD = 0.7) Statistical analysis shows that students like the robotic lessons (Mean = 4.6, SD = 0.3) Statistical analysis shows that students would like to have more of such lessons; combining science with language learning (Mean = 4.7, SD = 0.4) Statistical analysis shows that students benefitted from the lesson (Mean = 4.5, SD = 0.4) Statistical analysis shows that students feel that this scientific lesson helped to broaden their prior knowledge of English language (Mean = 4.1, SD = 0.8) Statistical analysis shows that students feel that being taught in this science lesson in the English course enhanced their understanding on the specific topic (Mean = 4.1, SD = 0.6) Statistical analysis shows that students agreed that the materials used in the lesson intriguing (Mean = 4.7, SD = 0.7) Statistical analysis shows that students consider this experience positive (Mean = 4.7, SD = 0.2)	Robot helped the students to learn the content better	Absent	Enhance understanding of lesson

Table 4 (continued)

Author (Year)	Result	Interpretation (related to barriers and facilitators)	Barriers	Facilitators
Wang et al. (2021)	58.33% agreed that the course encouraged student's participation For the homework, two students' sensor calibration accuracy reached 99% and the remaining students' results all exceeded 98% 50% of students strongly agreed and 50% of students agreed that the course had clearly defined concepts and skills in their learning processes, respectively	Robots led to more participation in class	Absent	Promote participation in class
Winkelmann and Eberman (2020)	Overall, the mean sum confidence score reported by the participants improved from 68.41 ± 8.13 at preintervention intervention to 69.35 ± 9.44 (of 90) measured on the postintervention survey. We did not identify any significant differences (P-value = 0.439) 12 participants encountered technological issues before or during the encounter that required them to troubleshoot. As a result, 6 participants (10.9%) used asynchronous telemedicine (E.g, phone call with no video feed) with another 6 participants (10.9%) using a combination of asynchronous and synchro- nous telemedicine (E.g. using the telepresence robot for the video feed coupled with their cell phones for the audio, or using video telephony such as FaceTime [Apple Inc, Cupertino, CA])	Robot did not give the students more confidence in their learning Poor video function of the robot	Poor video ability of the robot	Boost in confidence

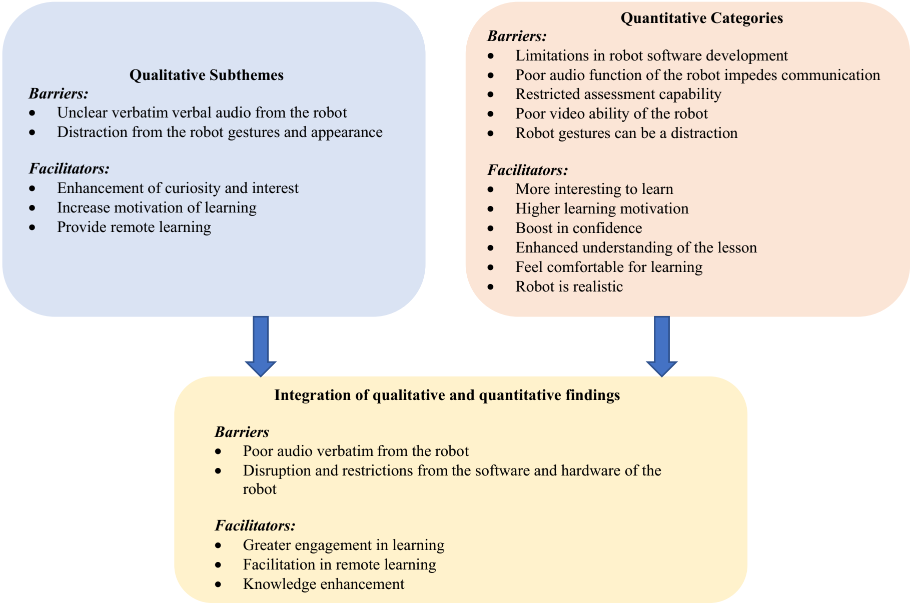

Fig. 2 Integration of quantitative and qualitative findings

4.1 Poor Audio Verbatim From the Robot

The findings of this review suggest that the learning of students in higher education is affected by the poor verbatim verbal audio of the robot. This finding is in line with those of previous reviews. Unintelligible low-resolution audio can result in a degraded learning experience as students cannot comprehend what the robot is saying, and vice versa. This problem affects the communication between the students and the robot, hence creating a barrier to the learning of the former. The verbatim verbal audio of the robot should then be improved given its effects on interaction quality and the overall appeal and enjoyment of the robot (Niculescu et al., 2013).

4.2 Disruption and Restrictions in the Software and Hardware of the Robot

The findings suggest that the students face disruption and restrictions in the software and hardware of the robot. They also observe limitations in the robot software development, where they had to spent time debugging the robot during their lessons. In terms of hardware, the students were distracted by the gestures and appearance of the robot. The current hardware development of the robot also restricted the assessment capability of the students. This problem is especially prominent among healthcare students undergoing simulations with telepresence robots. This finding is consistent with those of previous reviews (Zhang et al., 2021; Zhong & Xia, 2020). Given that the robot is a novel element in class, the students are unsurprisingly distracted by the use of this technology. Meanwhile, the low-resolution video of the robot can also impede the learning experience of students, especially that of healthcare students as they cannot see their patients properly and assess their conditions.

Table 5 Integration of quantitative and qualitative studies for barriers and facilitators of robot-assisted education

Selected articles from qualitative studies	Barriers	Facilitators	Selected articles from quantitative studies	Barriers	Facilitators
Aroca et al. (2013) Cruz-Martín et al. (2012)		Enhance curiosity and interest	Aroca et al. (2013) Donnermann et al. (2020) Kurniawan et al. (2018) Lister et al. (2018) Rosenberg-Kima et al. (2020) Shimaya et al. (2021) Suárez-Gómez and Pérez-Holguín (2020) Ververi et al. (2020)		More interesting to learn
Uzun (2020) Banaeian and Gilanlioglu (2021)		Increase motivation	Cruz-Martín et al. (2012) Donnermann et al. (2021) Guo et al. (2014) Gyebi et al. (2017)		Higher learning motivation
Corsby and Bryant (2020) Gleason and Greenhow (2017) Shaw et al (2018)		Robot gave remote presence	Lister et al. (2018) Molloy et al. (2016) Shaw et al. (2018) Winkelmann and Eberman (2020)		Boost in confidence
Banaeian and Gilanlioglu (2021) Gleason and Greenhow (2017) Rosenberg-Kima et al. (2020) Wong et al. (2021)	Unclear audio		Cruz-Martín et al. (2012) Donnermann et al. (2020) Gomez-de-Gabriel et al. (2011) Guo et al. (2014) Ibrahim et al. (2020) Li et al. (2016) Shaw et al. (2018) Shimaya et al. (2021) Suárez-Gómez and Pérez-Holguín (2020) Sun et al. (2017)		Enhance understanding of lesson

Table 5 (continued)

Selected articles from qualitative studies	Barriers	Facilitators	Selected articles from quantitative studies	Barriers	Facilitators
Banaeian and Gilanlioglu (2021) Corsby and Bryant (2020) Donnermann et al. (2021)	Robot can be a distraction		Banaeian and Gilanlioglu (2021) Donnermann et al. (2020) Sun et al. (2017)		Feel comfortable for learning
			Scott et al. (2020) Lister et al. (2018)		Robot is realistic
			Kurniawan et al. (2018)	Limitations in robot software development	
			Banaeian and Gilanlioglu (2021) Lister et al. (2018) Shaw et al. (2018)	Poor audio function of robot impedes communication	
			Lister et al. (2018) Shaw et al. (2018)	Restricted assessment capability	
			Donnermann et al. (2020)	Robot gesture can be a distraction	
			Shaw et al. (2018) Winkelmann and Eberman (2020)	Poor video ability of the robot	

4.3 Greater Engagement in Learning

The findings suggest that the use of robots improves the engagement of students in their learning by increasing their motivation and piquing their interest. These robots also increase the confidence of these students and encourage their class participation. These findings are in line with those of earlier studies, which suggest that robot-assisted education can engage higher education students in their learning (Chin et al., 2014; Gerecke & Wagner, 2007; McGill, 2012; Michaelis & Mutlu, 2019). According to constructivism theory, learned knowledge is influenced by what learners know and experience. Papert (1980) extended this thought by introducing the concept of constructionism, which states that learning occurs when a student produces a physical item and reflects on the motivation behind such action. The idea of constructionism is reflected in the use of robots in education (Kabátová & Pekárová, 2010). Constructionism is often adopted in the robotics curriculum, which largely involves hands-on practice, thus encouraging students to become critical thinkers and creative problem solvers. Constructionism can be used to understand the mechanism behind this theme. Traditionally, teachers are viewed as sources of knowledge for students (Dobrosovestnova, 2019). However, such perspective is rejected by the supporters of constructionism, who believe that knowledge should be viewed as instrumental. Therefore, robots can be viewed as bridges that help students understand their learning content. This argument is exemplified by Mubin et al. (2012), in which the participants studied how humans perceive speech by looking at how robots understand speech. This finding is also consistent with the constructionist hypothesis, which posits that learning is based on what students know and infer from their actual and virtual worlds. Therefore, in a constructionist learning environment, when treated as active learners, students can be effectively engaged (Li & Guo, 2015).

4.4 Facilitation in Remote Learning

The findings reveal that the use of robot-assisted education can facilitate remote learning. This finding has been confirmed in previous reviews (Yousif, 2021). The specific robot in this case is a telepresence robot, whose most monumental advantage is promoting intercontinental communication and interaction among people (Yousif, 2021). Using these robots is especially useful for employing foreign language teachers. With their wide range of employment opportunities all over the world, foreign language teachers can benefit from the use of robots, which would save them time and money in traveling to other countries. In other words, robots provide these teachers an uncompromised academic experience that is usually delivered in person.

4.5 Knowledge Enhancement

Knowledge enhancement is a result of robot-assisted education. Using robots can help students better understand their lesson content and improve their performance in examinations. These findings are in line with those of previous reviews (Michaelis & Mutlu, 2019). The mechanism behind this theme can be better understood from the lens of theory of constructivism, which posits that human learning is constructed and that learners layer new information on top of their existing knowledge (Sarita, 2017). Individuals will try to make sense of all information they perceive and will so "construct" their own meaning from such information. Therefore, by using robot-assisted education, students utilize their own understanding to comprehend their lesson content and reinforce their lesson objective. Therefore, knowledge enhancement is a positive outcome of robot-assisted education.

4.6 Strengths and Limitations

Using a three-step search procedure, studies conducted across 14 countries were identified from over 10 databases. A systematic and rigorous approach was then applied to conduct this mixed-studies review to gather high-quality evidence. A wide range of studies were included in the review to obtain a comprehensive picture of the barriers and facilitators that higher education students face while using robots in learning. The findings of this review not only contribute to the extant body of knowledge but also bolster the theories proposed by other academics. MMAT was used to critically evaluate all the selected studies, and the majority of the studies were confirmed to have high methodological quality. Despite adhering to the recommendations of data synthesis processes and the use of two independent reviewers, the credibility of the findings of this review may be influenced when low-quality studies are included. The restrictions in language present another limitation. Specifically, the inclusion of exclusively English language studies may result in the omission of some important studies. Furthermore, qualitative synthesis was carried out using only the data presented in the selected papers; therefore, the results may not be indicative of all original data. This limitation may affect how the data in this study are interpreted. Despite the vast range of robots utilized in the reviewed studies, all these studies focused on the use of robots for student teaching and learning, and the findings emphasized in this review were also found in these investigations.

5 Conclusion and Future Work

This systematic review identified barriers and facilitators of robot-assisted education in higher education. Use of robot-assisted education brought to light the role of robots in engaging students. It can be an effective and helpful teaching method by boosting the confidence of students and facilitating their remote learning. To enhance the learning of higher education students, robot-assisted education presents an alternate educational technique. It can be utilized to supplement and augment the ongoing higher education teaching arrangements. However, when utilizing robot-assisted education, the relevant technological challenges should be addressed to maintain the standards of teaching and learning. Future studies should examine the use of a specific type of robot in a comparable learning environment. Researchers should also employ highly stringent methodologies to improve the credibility of their findings and ensure the quality of their studies. More primary studies, preferably RCTs, should also be performed to further understand the barriers and facilitators of robot-assisted education. Randomization eliminates bias and provides a rigorous method for examining the cause–effect relationship between robot-assisted education and higher education students (Hariton & Locascio, 2018).

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Delarations

Conflict of interest The authors report no declarations of interest.

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