Contemporary Educational Technology, 2023, **15**(3), ep428
ISSN: 1309-517X (Online)

OPEN ACCESS

Review Article

Collaborative learning and skill development for educational growth of artificial intelligence: A systematic review

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Citation: Mena-Guacas, A. F., Urueña Rodríguez, J. A., Santana Trujillo, D. M., Gómez-Galán, J., & López-Meneses, E. (2023). Collaborative learning and skill development for educational growth of artificial intelligence: A systematic review. *Contemporary Educational Technology, 15*(3), ep428. https://doi.org/10.30935/cedtech/13123

ARTICLE INFO

Received: 13 Dec 2022
Accepted: 17 Feb 2023

ABSTRACT

The diversity of topics in education makes it difficult for artificial intelligence (AI) to address them all in depth. Therefore, guiding to focus efforts on specific issues is essential. The analysis of competency development by fostering collaboration should be one of them because competencies are the way to validate that the educational exercise has been successful and because collaboration has proven to be one of the most effective strategies to improve performance outcomes. This systematic review analyzes the relationship between AI, competency development, and collaborative learning (CL). PRISMA methodology is used with data from the SCOPUS database. A total of 1,233 articles were found, and 30 passed the inclusion and exclusion criteria. The analysis of the selected articles identified three categories that deserve attention: the objects of study, the way of analyzing the results, and the types of AI that could be used. In this way, it has been possible to determine the relationship offered by the studies between skill development and CL and ideas about AI's contributions to this field. Overall, however, the data from this systematic review suggest that, although AI has great potential to improve education, it should be approached with caution. More research is needed to fully understand its impact and how best to apply this technology in the classroom, minimizing its drawbacks, which may be relevant, and making truly effective and productive use of it.

Keywords: artificial intelligence, collaborative learning, skills development, educational development

INTRODUCTION

The current revolution brought about by the emergence of artificial intelligence (AI) is transforming the way people live and interact with technology (Makridakis, 2017). Some of the features of AI, such as machine

learning, have the potential to completely change many fields of knowledge as we understand them today (Wang & Siau, 2019). AI is being used to develop intelligent systems that can operate autonomously, improve decision-making processes and even provide human-like capabilities, such as natural language processing.

These particulars impact how education is delivered and received today enormous (Pereira et al., 2022; Celik et al., 2022). To positive use, AI-based tools and systems can personalize learning experiences, improve teacher productivity and enhance student attention. Virtual tutors could even be used to offer personalized attention to students in need and provide them with real-time feedback and support. However, while the benefits of AI in education may be numerous, it is crucial to approach this integration with caution and consider the ethical implications (Coeckelbergh, 2020). Furthermore, it is essential to ensure that AI systems are designed to augment and support human teachers rather than replace them.

In this context, we could think about the possibilities of AI in collaborative learning (CL) and competency development, the basis of contemporary pedagogical approaches. CL allows students to work together to explore and understand concepts, enabling a more profound understanding than can be achieved with traditional teaching methods. It focuses on the role of social interaction and teamwork in learning, where students work together to achieve common goals (Major, 2020). It fosters the development of essential skills such as communication, critical thinking, and problem-solving (Ghavifekr, 2020).

The development of competencies is also likewise determinant (Ferreira, 2013), as it allows students to become more proficient in understanding and applying the topics covered in class. CL and skill development can be enhanced through technology, such as online forums, blogs, and other web-based tools (Molinillo et al., 2018). They enhance blended learning, gamification, and project-based learning, so relevant in new pedagogies. They also develop relevant 21st-century skills, such as digital literacy. And among all these technologies, AI can undoubtedly stand out with the possibilities we have mentioned.

To improve the integration of AI in education, it would be crucial to establish the connections between CL and the development of competencies. Once configured, it would be necessary to specify which types of AI would be the most appropriate for its development. The complexity of today's organizational databases highlights the importance of complex technical skills as well as soft skills (Mitchell & Vaughan, 2022) and CL improved students' readiness for the workforce (Cioc et al., 2022) and transferable skills (Larraz et al., 2017), including improving one's ability to work with other students on assignments, listening to the ideas of others, learning from the ideas of others, and evaluating the ideas of others (Cioc et al., 2022). The skills or competencies required may be generic or specific. On the one hand, to face the challenges demanded by a changing and uncertain world, students need to develop generic competencies during their studies (Mykytiuk et al., 2022). On the other hand, today's companies require a workforce with specific competencies to perform increased complexity tasks (Marchi et al., 2019).

There are several ways in which skills (or competencies) development can be strengthened, e.g., incorporating interactive digital learning objects (McGuinness & Fulton, 2019), the use of small-space games (Bennett et al., 2018), behavioral skills training (Kirkpatrick et al., 2019), among others. CL is also one form, evidenced by the consistency with which studies have found evidence that peer interactions contribute to student achievement outcomes (Shafipour et al., 2018).

When collaboration manages to consolidate, educational action is more enjoyable and effective (Lee et al., 2011), individual learning outcomes are increased, and student satisfaction is better (Kwon et al., 2014, Kurucay & Inan, 2017; Hernández-Sellés, 2021). In addition, CL fosters students' sense of community, belonging, and influence (Luo et al., 2017) and contributes to maintaining emotional support (Hernández-Sellés et al., 2019), and is an indicator of student progress and student groups (Yucel & Usluel, 2016). Both the interaction between students and between them and the teacher are relevant to the collaborative process (Hernández-Sellés et al., 2019). However, each contributes differently: collaboration among students is fundamental for knowledge-building and competency development (Pulgar et al., 2022), while teacher-student interaction positively influences students' active learning (Molinillo et al., 2018).

However, CL has not been able to accurately master the information (Rui & Ying-Yan, 2012) generated in the interaction between actors. This is one of the reasons why one of the seven subjects most outstanding in AI in education is CL (Feng & Law, 2021). Also, computer-supported collaborative learning (CSCL) has gotten much attention in AI (Ul Haq et al., 2020). This interest has even led to the proposal of a new conceptual

Table 1. Search code

Codes
SCOPUS (21/09/2022): TITLE-ABS-KEY (interaction OR collaboration AND "skills development" OR "competency development" OR "development of competences" OR "developing skills" OR" development of skills" OR "competence development" OR "development of competencies") AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015) OR LIMIT-TO (PUBYEAR, 2014) OR LIMIT-TO (PUBYEAR, 2013)) AND (LIMIT-TO (LANGUAGE, "English") OR LIMIT-TO (LANGUAGE, "Spanish"))

framework called "intelligent tutoring supported collaborative learning (ITSCL)" (UI Haq et al., 2020). In the studies that have been done, teachers found the AI assistant helpful in collaborative learning environments because this technology can support the actions of teachers who implement the CL strategy, helping to detect students with needs and providing suggestions for intervention (Kasepalu et al., 2022).

AI has permeated all aspects of the educational field (Suning & Zhang, 2020), but the diversity of topics makes it difficult to address them all in depth, so the efforts are not enough development should focus on those lines that could generate more significant contribution. The analysis of the development of competencies through the promotion of collaboration should be one of them because competencies are the way to validate that the educational exercise has been successful and because collaboration is one of the most effective strategies to improve performance outcomes. Considering the above, two questions are proposed in this systematic review:

(1) What are the characteristics of the studies that have been carried out about the relationship between skills development and CL? and

(2) What should AI focus on to contribute to the understanding of competence development through CL?

MATERIALS AND METHODS

Methodology

A systematic review was carried out in SCOPUS, and the PRISMA methodology was used. The search was done by crossing two of the three concepts (CL and development of competencies), which are the most frequently found in the available research, thus making it possible to answer the first question posed. The search algorithm is shown in **Table 1**. The concept of AI was not used in the search because it was the criterion for analyzing the documents. This issue is further elaborated in below.

Inclusion and Exclusion Criteria

Inclusion and exclusion criteria were defined to identify manuscripts to be included in the review.

Inclusion criteria

Mention or describe any relationship between interaction/collaboration and the development of some competence (for example, general, transversal, and specific, but it does not matter if classification is different).

Exclusion criteria

1. The interaction is not between people.
2. The concept of competence is associated with the dispute, contest, or competition and not with expertise, aptitude, skill, or suitability.
3. It is not possible to access the complete document.
4. It is theoretical research.

Selection of Papers

With the search code, a total of 1,233 articles were found; after reading the title and considering the inclusion and exclusion criteria, 981 articles were eliminated. The remaining 252 were processed by reading the abstract, and 219 were eliminated. Three papers were discarded because the complete document was not available. 30 works were included for the analysis by full screening test (**Figure 1**).

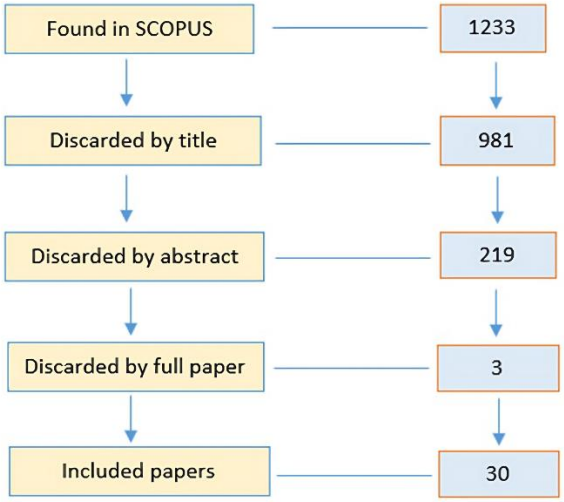

Figure 1. Flowchart of relevant article selection (adapted from Dreifuss et al., 2018)

Table 2 shows the list of the 30 papers selected, indicating the title, authors and year of publication.

Table 2. Papers information

Title	Author(s)	Year
Juxtaposing generic skills development in collaborative knowledge work competences and related pedagogical practices in higher education	Muukkonen et al.	2022
Long-term collaboration with strong friendship ties improves academic performance in remote and hybrid teaching modalities in high school physics	Pulgar et al.	2022
From resistance to acceptance in small group work: Students' narratives	Wong et al.	2022
Improved self-assessed collaboration through interprofessional education: Midwifery students and obstetrics and gynecology residents learning together	Avery et al.	2022
Facebook as a flexible ubiquitous learning space for developing speaking skills	Mykytiuk et al.	2022
Students' experiences of the development of generic competences in the Finnish higher education context–The role of teaching-learning environment and approaches to learning	Myllykoski-Laine et al.	2022
Environmental capability development in a multi-stakeholder network setting: Dynamic learning through multi-stakeholder interactions	Baranova	2022
A model for incorporating information literacy and collaboration in a project-based learning pedagogical exercise with application to a fluid mechanics course	Cioc et al.	2022
Implementing team-based learning: Findings from a database class	Mitchell and Vaughan	2022
Synchronous virtual environment and its effect on the development of a health program in the context of the pandemic	Infante et al.	2021
The relevance of interaction in virtual learning environments during COVID-19	Hernández-Sellés	2021
Will the COVID-19 pandemic leave a lasting legacy in children's skill development?	Werner and Woessmann	2021
Role of college environment on students' soft skills: Achievement goal structure	Zhang et al.	2021
Pedagogical strategies for the learning and development of research competences in university students	Hernández et al.	2021
Collaborative problem-solving efficacy in cognitive linguistic skill development and in the academic performance in physics	Sánchez et al.	2020
The effect of peer learning on professional competence development among Indonesian undergraduate nursing students: A quasi-experimental study	Nelwati et al.	2020
Maternal synchrony associated with academic performance in school-age children	Negrete-Cortés et al.	2020
Postdocs' lab engagement predicts trajectories of PhD students' skill development	Feldon et al.	2019
The impact of international stays on the development of skills in doctoral students and their transfer in various contexts	Magnani et al.	2019
Classroom interaction practices and students' learning outcomes in physics: Implication for teaching-skill development for physics teachers	Achor et al.	2019
Authentic undergraduate research in plant science: The importance of mentor-student relationships	Doerflinger et al.	2019
Buildup of speaking skills in an online learning community: A network-analytic exploration	Shafipour et al.	2018
Research integration in information systems education: Students' perceptions on learning strategies, skill development, and performance	Natsis et al.	2018

Table 2 (Continued). Papers information

Title	Author(s)	Year
Effects of perceptions of the learning environment and approaches to learning on Chinese undergraduates' learning	Guo et al.	2017
Tensions in mentoring medical students toward self-directed and reflective learning in a longitudinal portfolio-based mentoring system–An activity theory analysis	Heeneman and de Grave	2017
Collaborative work competency in online postgraduate students and its prevalence on academic achievement	Castillo et al.	2017
Transversal skills development through cooperative learning. Training teachers for future	Larraz et al.	2017
A structural model of the relationship between student–faculty interaction and cognitive skills development among college students	Kim and Lundberg	2016
Classroom interaction and thinking skills development through teacher-talks	Abhakorn	2013
Effects of synchronous computer-mediated communication and face-to-face interaction on speaking skill development of Iranian EFL learners	Mehr et al.	2013

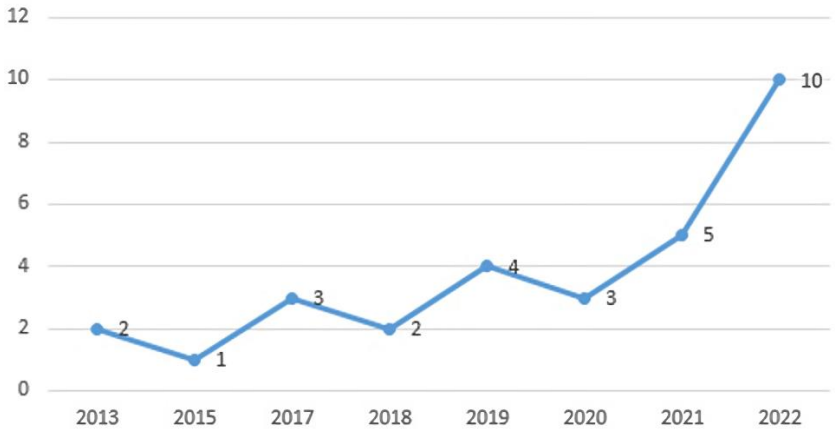

Figure 2. Number of papers per year (Source: Authors)

Table 3. Subjects or disciplines

Subjects or disciplines	Papers
Research	14, 18, 19, & 24
Language	15, 22, & 30
Physics	4 & 20
Sustainability	7
Engineering	8
Health	10
Nursing	16

RESULTS

Main Findings

The evolution of the number of publications about skills development through collaboration is positive and will grow exponentially in 2022 (**Figure 2**). Four of the eighteen articles published between 2018 and 2022 explicitly mention COVID-19.

Table 3 shows information about the subjects or disciplines in which CL is applied to develop competencies.

Regarding ways of interaction

25 papers mention the relationship between the interaction and the development of competencies or skills directly, 27 papers indicate that there is a positive correlation between CL and skill development, 19 exhibits a face-to-face (FTF) interaction, nine computer-mediated interaction (CMI), one does not mention (NM), and one presents both interactions FTF and CMI (**Figure 3**). Over time, the interaction that stands out the most is face-to-face (**Figure 4**).

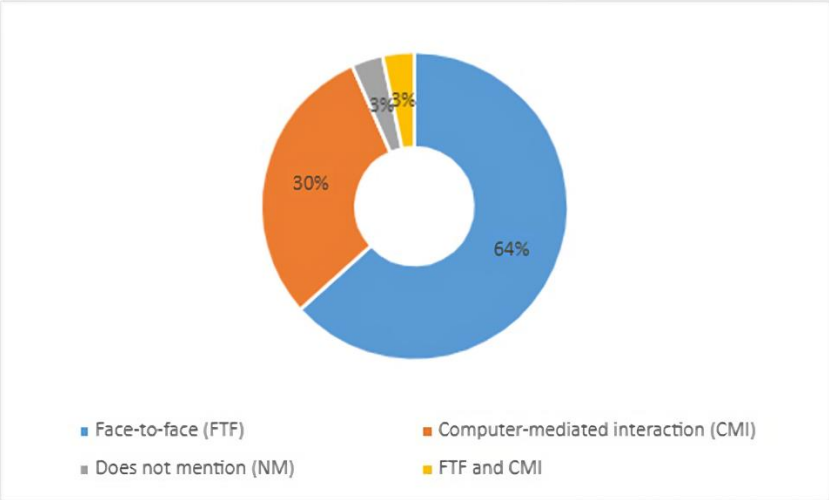

Figure 3. Percentage of items according to interaction type (Source: Authors)

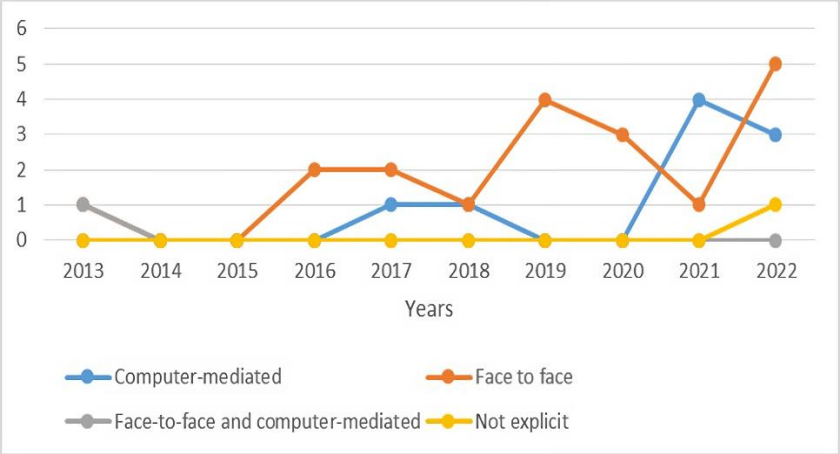

Figure 4. Ways of interaction (Source: Authors)

Table 4. Skills studied

Skills	Paper ID	Total	Skills	Paper ID	Total
Cognitive	[11, 12, 15, 17, 20, 22, 23, 26-30]	12	Socioemotional	[12]	1
Communicative and linguistics	[1, 3, 5, 8, 14, 15, 19, 22, 28, 29]	10	Research	[14]	1
Collaborative work/teamwork	[1, 3, 8, 9, 26 27]	6	Propositional	[14]	1
Soft skills/generic	[6, 13, 18, 21, 24, 25]	6	Technological	[14]	1
Professionals or specific	[4, 8, 10, 16]	4	Interpersonal	[14]	1
Behavioral	[14, 17, 20]	3	Procedural	[14]	1
Relationship	[7]	1	Analytical	[14]	1
Structured tasks	[2]	1	Intercultural	[19]	1
Sustainability	[7]	1	Creativity	[23]	1

Regarding the skills studied in the papers in contrast to collaborative learning

Table 4 presents the list and the studies related to each. Some arouse more interest than others: cognitive, communicative, linguistics, collaborative work, teamwork, generic, and soft skills. It is essential to mention that 27 articles included in the systematic review found a positive relationship between interaction and the development of competencies.

Figure 5 shows the skills influenced by collaboration mentioned in papers over the last ten years. The slope of the curve is increasing.

Another important issue is to know the actors involved in the collaboration. **Figure 6** shows the different types.

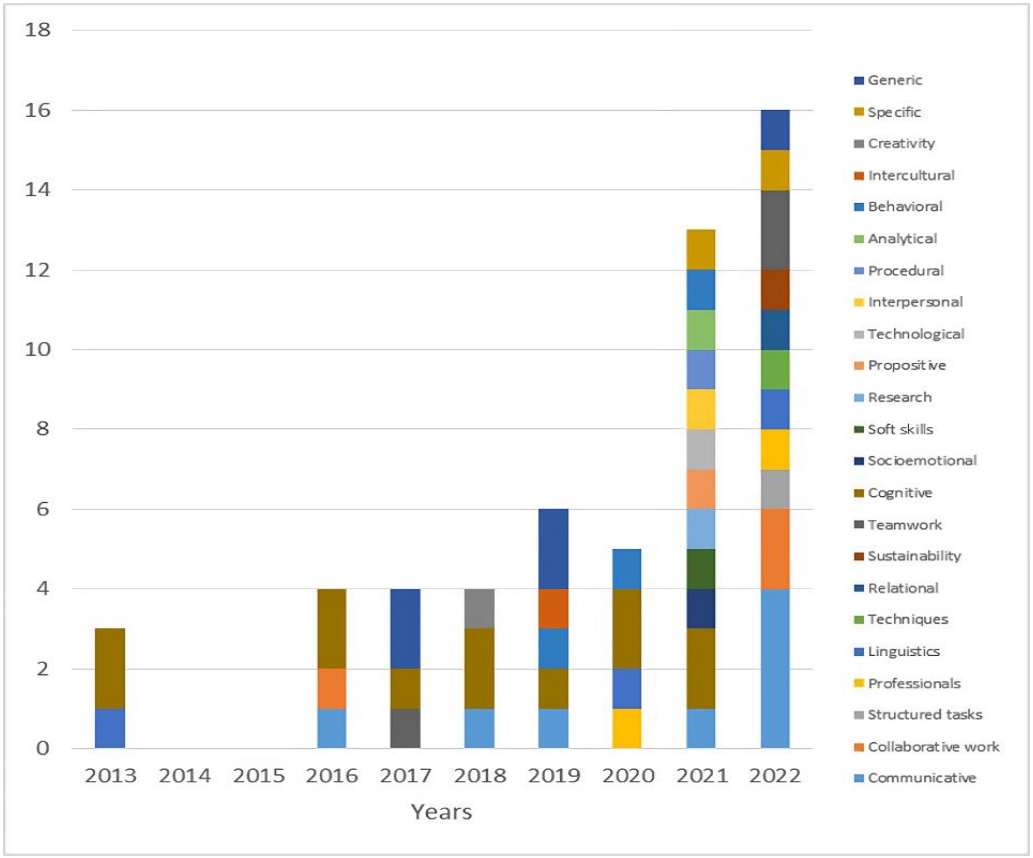

Figure 5. Skills studied in the analyzed articles (Source: Authors)

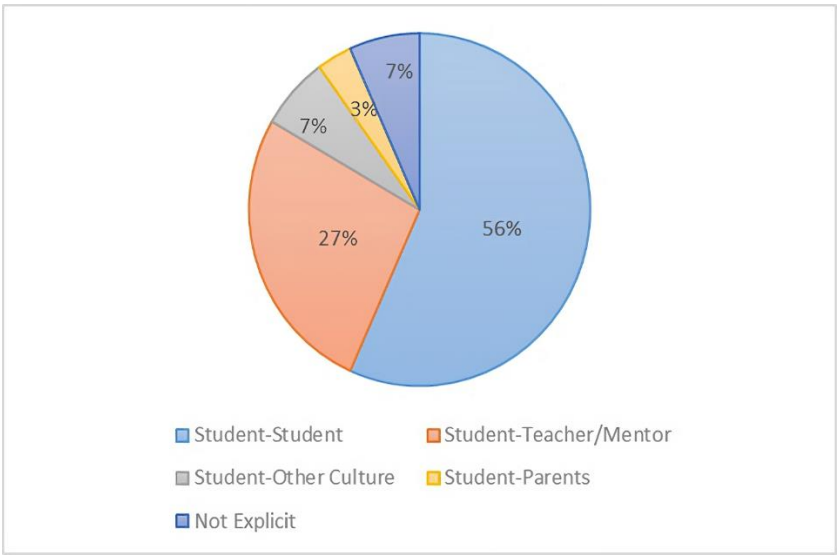

Figure 6. Actors who interact (Source: Authors)

In addition, **Figure 7** shows the evolution over time of the types of interaction studied.

To conclude the topic of developing competencies through collaboration, **Figure 8** shows the studies that encourage interaction through teamwork.

Regarding the second question of this systematic review

The analysis of the 30 selected articles identified three categories that deserve attention: the objects of study, how the results are analyzed, and the types of AI that could be used. These categories were proposed by Chee et al. (2022).

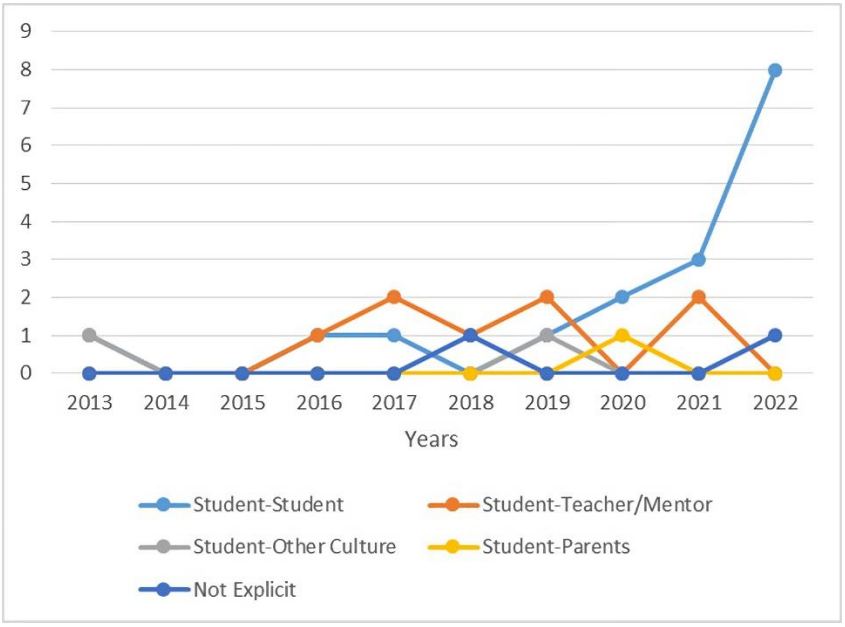

Figure 7. Evolution papers about actors who interact (Source: Authors)

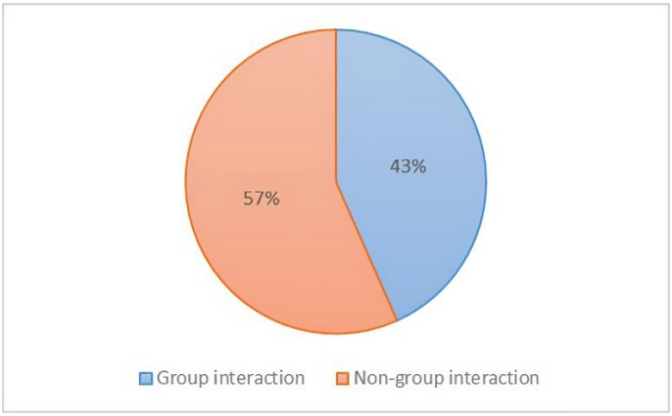

Figure 8. Group and non-group interaction (Source: Authors)

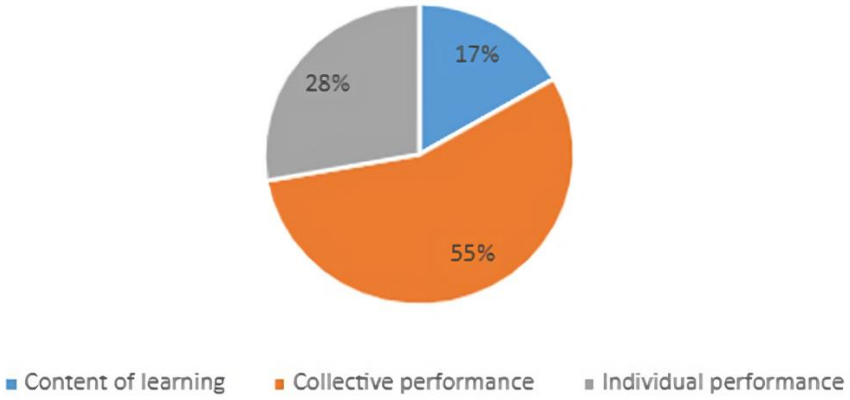

Figure 9. Percentage of papers, according to how the results are analyzed (Source: Authors)

How Results are Analyzed

Figure 9 shows the percentage, and **Figure 10** the evolution over time, or use of the three forms of analysis, which can be:

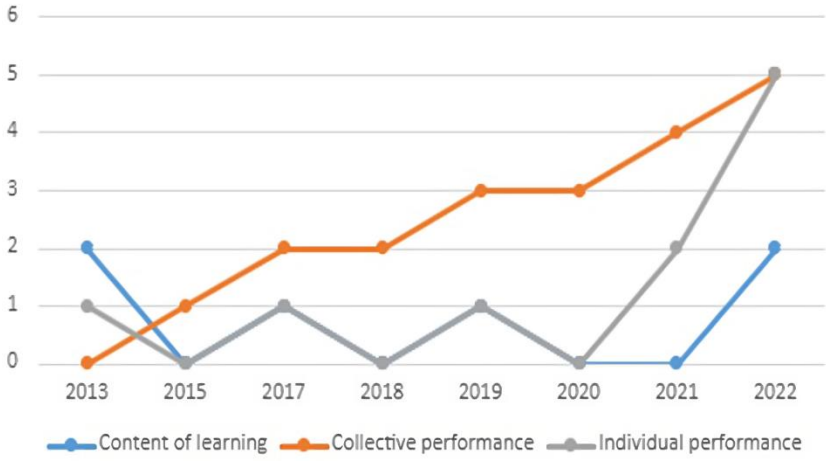

Figure 10. How results are analyzed in the papers by year (Source: Authors)

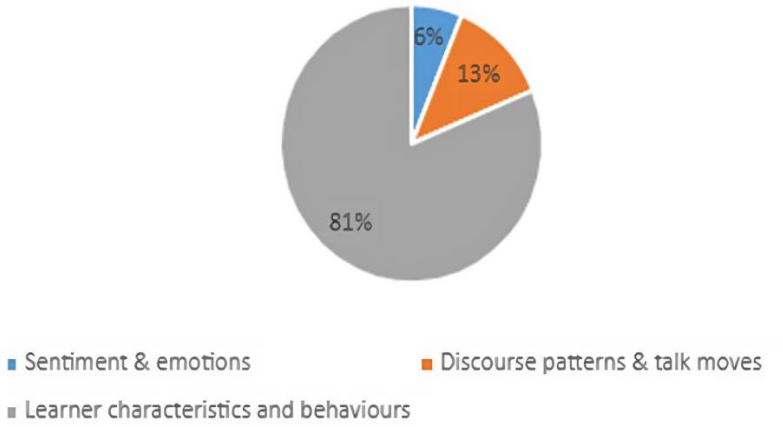

Figure 11. Percentage of papers, according to the topics of study (Source: Authors)

(a) Individual performance: analysis of each student's data;

(b) Collective performance: analysis of data for the entire group (data processing may be individual, but results are presented for the whole group); and

(c) Learning content: refers to the analysis of the products developed by students and can be individual or collective.

It is proposed as another category because the analysis of documents (texts, videos, etc.) is a highly used technique in AI.

The collective performance and learning content are subcategories defined by Chee et al. (2022). The category of individual performance emerged in the development of this systematic review.

Study Objects

In addition to skills, the most important object of study is related to the characteristics of learning (**Figure 11**), which has to do with academic performance, interest, and motivation, among others; moreover, interest in this topic has been growing since 2013 (**Figure 12**).

Types of Artificial Intelligence That Could be Used

Most of the studies are descriptive (**Figure 13**), and this is also the type that has been consolidated up to the year 2022 (**Figure 14**). The IA should support this type of study.

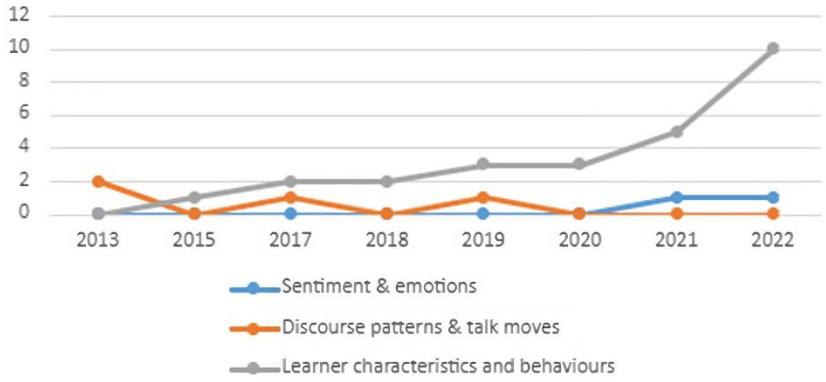

Figure 12. Topics of study, according to how the results were analyzed (Source: Authors)

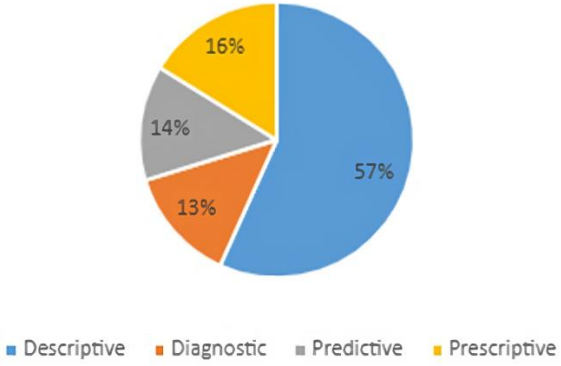

Figure 13. Percentage of papers, according to the types of artificial intelligence that could be used (Source: Authors)

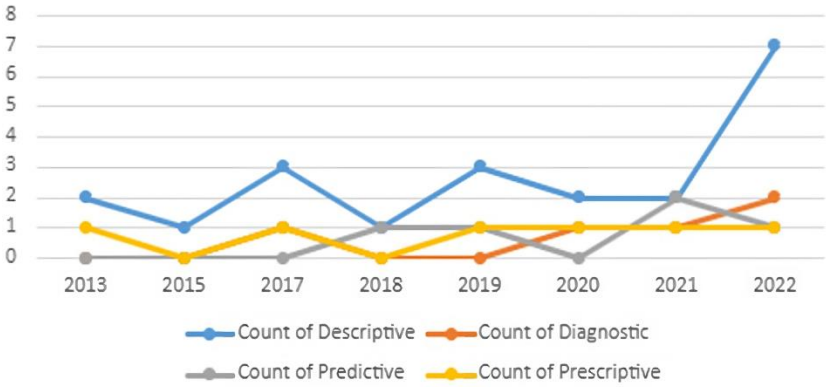

Figure 14. Topics of study, according to the types of artificial intelligence that could be used (Source: Authors)

DISCUSSION

The first hypothesis about the cause of the growth in publications about the development of skills through collaboration (**Figure 2**) is the COVID-19 pandemic because it prompted many people to learn about the possibilities of collaboration in digital environments.

Aguilar and Perez (2021) point out that CL is essential to a new educational approach characterized by social isolation and virtual learning experiences because of COVID-19. Other studies, such as Almusharraf and Bailey (2021), Dewi and Muhid (2021), Handini et al. (2022), Mustakim et al. (2021), and Safta-Zecheria et al. (2021), and also highlighted the importance of CL during the pandemic and the positive results obtained with it.

The data from this systematic review suggest that this may not be the final answer since many of the papers reviewed present experiences before the pandemic or face-to-face interactions (**Figure 2**), and only 22% of the papers published between 2020 and 2022 explicitly mention the pandemic. The rest may have taken the data earlier or do not expressly mention it as an element they consider relevant to the research, which shows that interest in the topic is not only a result of the pandemic. Moreover, it coincides with the findings of Feng and Law (2021), who mentioned that CL is one of the most studied education topics with AI.

Although there is a tendency to develop isolated studies by discipline (García-Chitiva, 2021), research on skills development through collaboration is done in almost all of them (**Table 3**). This shows that the interest in developing skills supported by collaboration does not depend on discipline.

Only one article combines face-to-face and computer-mediated interaction (**Figure 3**). There is still a predilection for face-to-face interaction, even though teaching in 21st-century higher education is moving towards e-Learning or b-Learning teaching models (Sáiz-Manzanares et al., 2021). This may happen because educational institutions have been slowly moving to transform their offerings towards e-learning and b-learning. The COVID-19 pandemic has changed the face of higher education, many universities have adopted the hybrid or blended medium of instruction (Singh et al., 2021), so the modality transformation could be much more accelerated in the coming years.

Research on the correlation between collaboration and skills development has aroused more significant interest in studies conducted in education, with a powerful tendency to increase over time. For example, in 2013, articles only mention the influence of interaction in two competencies (linguistic and cognitive), while in 2022, its influence is noted in eleven (generic, specific, teamwork, sustainability, relational, technical, linguistic, professional, structural tasks, collaborative work and communicative) (**Figure 5**). This shows that collaboration has been found to contribute to more competencies than initially thought. Several studies in different fields of learning, such as those by Gómez-Galán (2020), Hei et al. (2020), Herrera-Pavo (2021), and López-Meneses (2020), and have presented the reality of this fact.

The type of interaction most often studied is between students (**Figure 6**), indicating that teachers and tutors recognize that students have managed to self-regulate and self-manage their learning. In addition, student-student relationships can play a role in contributing to transformative learning and lead to personal growth (Kelleher, 2020) and is one of the aspects that allow for a harmonious classroom environment (Luo et al., 2022). This shows that the decision to prioritize the study of student-student interaction is a wise one.

Regarding the second question proposed for this review, AI algorithms should concentrate efforts on analyzing the entire group (**Figure 9**), but in the educational exercise, it is essential to have individual data for decision-making and strategy design. In a similar way, although in other technological contexts, authors such as Pastora and Fuentes (2021) and Webber and Zheng (2020) have an impact on this issue. This is reinforced by what is seen in 2022, as the interest in individual performance equaled the collective (**Figure 10**). This shows that the potential use of algorithms will be more significant as they provide data about the development of competencies at the individual and group levels. This does not imply that the indicators or analyses are the same at both levels, but both must be carried out. For example, at the individual level, the processing of the content of a student's document would be automated with AI to identify the development of competency and cross-referenced with the quality of their interaction, while at the group level, group patterns would be placed.

Sentiment analysis has not been used much in the study of competence development through collaboration (**Figure 11**), but it has been explored in depth in the AI field. Such an advance would make a significant contribution in this field because positive feelings favor interaction, promoting collaboration and skills development. This has been pointed out in several studies, e.g., (Zhipeng et al., 2022) pointed out that to achieve satisfactory learning outcomes, students must maintain positive emotions during the CL process, and Dehbozorgi et al. (2021) said that there is a strong positive correlation between students' positive emotions while interacting with each other with their performance in the course. Sentiments, interaction, collaboration, and competencies are four elements connected, so it is necessary to analyze them together, and AI can support this task. The line of work could be to explore the participants' feelings and the interaction that occurs in learning environments; then, it would be necessary to assess the collaboration achieved between students and teachers through how they interact and finally to evaluate the development of

competencies. Discourse patterns are another advanced topic in AI, as discussed by Chee et al. (2022) and Dowell et al. (2019) but developing competencies through collaboration is not yet sufficiently addressed.

From another perspective, the results show that descriptive studies abound (**Figure 13** and **Figure 14**), but those that provide decision-making inputs (predictive and diagnostic) are almost not carried out. In contrast, the research in AI-assisted decision-making is experiencing tremendous growth (Schemmer et al., 2022) because it provides insights and methods that enable decision-making (Yong et al., 2022). Consider CL as a practical resource for developing competencies with AI, for example, defining the most effective way to distribute learners in groups for all participants and assessing the quality of interaction in learning environments, among others.

CONCLUSIONS

Conclusions are proposed based on the two questions formulated for this review:

(a) What are the characteristics of the studies that have been carried out about the relationship between skills development and CL and

(b) What should AI focus on to contribute to the understanding of competence development through CL?

Regarding the first one, it is essential to mention that studies on developing competencies through collaboration are rising. The main characteristics of the studies are that they contribute to different areas or disciplines and prioritize face-to-face interaction, and since 2019 there has been an increasing interest in computer-mediated interaction. The most studied skills are cognitive, communicative, collaborative, and generic or soft skills. Finally, the interaction between students is the one that arouses the most interest among researchers. About the second question, AI development efforts could focus on algorithms that enable collective and individual performance analysis, boost the study of sentiment, and provide tools for diagnostic and predictive analysis that focus on providing information for decision-making.

AI has become an increasingly popular topic in recent years, and interest in investigating its potential educational applications has increased, but much remains to be explored in this area. In addition, although it has great potential to improve education, it should be approached with caution. More research is needed to fully understand its impact and how best to implement these technologies in the classroom, minimizing its drawbacks, which may be relevant, and making a truly effective and productive use of it.

Author contributions: AFM-G, JAUR, & DMST: conceptualization, methodology, formal analysis, investigation, data curation, writing-original draft preparation, writing-review & editing, supervision, & project administration & **JG-G & EL-M:** writing-original draft preparation, writing-review & editing, investigation, & supervision. All authors approved the final version of the article.

Funding: The authors received no financial support for the research and/or authorship of this article.

Ethics declaration: Authors declared that no ethics committee approval was required since the study is a review of existing literature.

Declaration of interest: Authors declare no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

REFERENCES

Abhakorn, J. (2013). Classroom interaction and thinking skills development through teacher-talks. *Kasetsart Journal of Social Sciences, 34*(1), 116-125.

Achor, E. E., Danjuma, I. M., & Orji, A. (2019). Classroom interaction practices and students' learning outcomes in physics: Implication for teaching-skill development for physics teachers. *Journal of Education and E-Learning Research, 6*(3), 96-106. https://doi.org/10.20448/journal.509.2019.63.96.106

Aguilar, O. G., & Perez, A. B. D. (2021). Integration model for collaborative learning in COVID-19 times: Validation of the constructivist online learning environment survey (COLLES). In *Proceedings of the 16th Iberian Conference on Information Systems and Technologies* (pp. 1-5). IEEE. https://doi.org/10.23919/CISTI52073.2021.9476272

Almusharraf, N. M., & Bailey, D. (2021). Online engagement during COVID-19: Role of agency on collaborative learning orientation and learning expectations. *Journal of Computer Assisted Learning, 37*(5), 1285-1295. https://doi.org/10.1111/jcal.12569

Avery, M. D., Mathiason, M., Andrighetti, T., Autry, A. M., Cammarano, D., Dau, K. Q., & Jennings, J. C. (2022). Improved self-assessed collaboration through interprofessional education: Midwifery students and obstetrics and gynecology residents learning together. *Journal of Midwifery & Women's Health, 67*(5), 598-607. https://doi.org/10.1111/jmwh.13394

Baranova, P. (2022). Environmental capability development in a multi-stakeholder network setting: Dynamic learning through multi-stakeholder interactions. *Business Strategy and the Environment, 31*(7), 3406-3420. https://doi.org/10.1002/bse.3091

Bennett, K., Novak, A., Pluss, M., Stevens, C., Coutts A., & Fransen, J. (2018) The use of small-sided games to assess skill proficiency in youth soccer players: A talent identification tool. *Science and Medicine in Football, 2*(3), 231-236. https://doi.org/10.1080/24733938.2017.1413246

Castillo, M., Heredia, Y., & Gallardo, K. (2017). Collaborative work competency in online postgraduate students and its prevalence on academic achievement. *Turkish Online Journal of Distance Education, 18*(3), 168-179. https://doi.org/10.17718/tojde.328949

Celik, I., Dindar, M., Muukkonen, H., & Järvelä, S. (2022). The promises and challenges of artificial intelligence for teachers: A systematic review of research. *TechTrends, 66*(4), 616-630. https://doi.org/10.1007/s11528-022-00715-y

Chee, S., Yen, A. V., & Lee, M. (2022). A systematic review of artificial intelligence techniques for collaborative learning over the past two decades. *Computers and Education: Artificial Intelligence, 3*, 100097. https://doi.org/10.1016/j.caeai.2022.100097

Cioc, C., Haughton, N., Cioc, S., & Napp, J. (2022). A Model for incorporating information literacy and collaboration in a project-based learning pedagogical exercise with application to a fluid mechanics course. *International Journal of Mechanical Engineering Education, 50*(4), 955-977. https://doi.org/10.1177/03064190221081450

Coeckelbergh, M. (2020). *AI ethics*. MIT Press. https://doi.org/10.7551/mitpress/12549.001.0001

Dehbozorgi, N., Maher, M., & Dorodchi, M. (2021). Does self-efficacy correlate with positive emotion and academic performance in collaborative learning? In *Proceedings of the IEEE Frontiers in Education Conference* (pp. 1-8). https://doi.org/10.1109/FIE49875.2021.9637471

Dewi, P., & Muhid, A. (2021). Students' attitudes towards collaborative learning through e-learning during COVID-19: A male and female students. *English Teaching Journal: A Journal of English Literature, Language and Education, 9*(1), 26-33. https://doi.org/10.25273/etj.v9i1.9046

Doerflinger, F. C., Able, A. J., & Loveys, B. R. (2019). Authentic undergraduate research in plant science: The importance of mentor-student relationships. *International Journal of Innovation in Science and Mathematics Education, 27*(4). https://doi.org/10.30722/IJISME.27.04.003

Dowell, N., Lin, Y., Godfrey, A., & Brooks, C. (2019). Promoting inclusivity through time-dynamic discourse analysis in digitally-mediated collaborative learning. In *Artificial Intelligence in Education: 20th International Conference* (pp. 207-219). Springer. https://doi.org/10.1007/978-3-030-23204-7_18

Dreifuss, C., Schreier, C., & Jumpa, M. (2018). *Criterios de clasificación de la vivienda informal: Una revisión sistemática PRISMA como herramienta para establecimiento y análisis de categorías* [*Informal housing classification criteria: A systematic review PRISMA as a tool for establishing and analyzing categories*]. https://repositorio.ulima.edu.pe/handle/20.500.12724/7387

Feldon, D. F., Litson, K., Jeong, S., Blaney, J. M., Kang, J., Miller, C., & Roksa, J. (2019). Postdocs' lab engagement predicts trajectories of PhD students' skill development. *Proceedings of the National Academy of Sciences, 116*(42), 20910-20916. https://doi.org/10.1073/pnas.1912488116

Feng, S., & Law, N. (2021). Mapping artificial intelligence in education research: A network-based keyword analysis. *International Journal of Artificial Intelligence in Education, 31*(2), 277-303. https://doi.org/10.1007/s40593-021-00244-4

Ferreira, M. (2013). Tutorial teaching: A new paradigm for the development of competencies. *Journal of Educational, Cultural and Psychological Studies, 8*, 205-219. https://doi.org/10.7358/ecps-2013-008-ferr

García-Chitiva, M. (2021). Collaborative learning in higher education processes mediated by internet. *Revista Electronica Educare* [*Electronics Education Magazine*]*, 25*(1). https://doi.org/10.15359/ree.25-2.23

Ghavifekr, S. (2020). Collaborative learning: A key to enhance students' social interaction skills. *Malaysian Online Journal of Educational Sciences, 8*(4), 9-21.

Gómez-Galán, J. (2020). *Innovation and ICT in education: The diversity of the 21st century classroom*. River Publishers.

Guo, J., Yang, L., & Shi, Q. (2017). Effects of perceptions of the learning environment and approaches to learning on Chinese undergraduates' learning. *Studies in Educational Evaluation, 55*, 125-134. https://doi.org/10.1016/j.stueduc.2017.09.002

Handini, O., Hidayatullah, M. F., & Akhyar, M. (2022). Analysis of collaborative learning models in online thematic learning during the pandemic COVID-19. In *Proceedings of the Universitas Lampung International Conference on Social Sciences* (pp. 677-683). Atlantis Press. https://doi.org/10.2991/assehr.k.220102.093

Heeneman, S., & de Grave, W. (2017). Tensions in mentoring medical students toward self-directed and reflective learning in a longitudinal portfolio-based mentoring system–An activity theory analysis. *Medical Teacher, 39*(4), 368-376. https://doi.org/10.1080/0142159x.2017.1286308

Hei, M., Tabacaru, C., Sjoer, E., Rippe, R., & Walenkamp, J. (2020). Developing intercultural competence through collaborative learning in international higher education. *Journal of Studies in International Education, 24*(2), 190-211. https://doi.org/10.1177/1028315319826226

Hernández, I., Lay, N., Herrera, H., & Rodríguez, M. (2021). Estrategias pedagógicas para el aprendizaje y desarrollo de competencias investigativas en estudiantes universitarios [Pedagogical strategies for the learning and development of research competences in university students]. *Revista de Ciencias Sociales* [*Social Science Journal*]*, 27*(2), 242-255.

Hernández-Sellés, N. (2021). Tools that facilitate collaborative learning in virtual environments: new opportunities for the development of digital learning ecologies. *Educatio Siglo XXI* [*Education Siglo XXI*]*, 39*(29), 81-100. https://doi.org/10.6018/educatio.465741

Hernández-Sellés, N., Muñoz-Carril, P., & González-Sanmamed, M. (2019). Computer-supported collaborative learning: An analysis of the relationship between interaction, emotional support and online collaborative tools. *Computers & Education, 138*, 1-12. https://doi.org/10.1016/j.compedu.2019.04.012

Herrera-Pavo, M. Á. (2021). Collaborative learning for virtual higher education. *Learning, Culture and Social Interaction, 28*, 100437. https://doi.org/10.1016/j.lcsi.2020.100437

Infante, L. J., Calderón, C. A., & Núñez, C. A. (2021). Entorno virtual sincrónico y su efecto en el desarrollo de un programa de salud en contextos de la pandemia [Synchronous virtual environment and its effect on the development of a health program in contexts of the pandemic]. *Boletín de Malariología y Salud Ambiental* [*Malariology and Environmental Health Bulletin*]*, 61*(4), 700-707. https://doi.org/10.52808/bmsa.7e5.614.018

Kasepalu, R., Prieto, L., Ley, T. and Chajara, P. (2022). Teacher artificial intelligence-supported pedagogical actions in collaborative learning coregulation: A wizard-of-oz study. *Frontiers in Education, 7*(17). https://doi.org/10.3389/feduc.2022.736194

Kim, Y. K., & Lundberg, C. A. (2016). A structural model of the relationship between student-faculty interaction and cognitive skills development among college students. *Research in Higher Education, 57*(3), 288-309. https://doi.org/10.1007/s11162-015-9387-6

Kirkpatrick, M., Akers, J. & Rivera, G. (2019). Use of behavioral skills training with teachers: A systematic review. *Journal of Behavioral Education, 28*, 344361. https://doi.org/10.1007/s10864-019-09322-z

Kwon, K., Liu, Y., & Johnson, L. (2014). Group regulation and social emotional interactions observed in computer supported collaborative Learning: Comparison between good vs. poor collaborators. *Computers & Education, 78*, 185-200. https://doi.org/10.1016/j.compedu.2014.06.004

Larraz, N., Vázquez, S., & Liesa, M. (2017). Transversal skills development through cooperative learning. Training teachers for the future. *On the Horizon, 25*(2), 85-95. https://doi.org/10.1108/OTH-02-2016-0004

Lee, S., Srinivasan, S., Trail, T., Lewis, D., & Lopez, S. (2011). Examining the relationship among student perception of support, course satisfaction, and learning outcomes in online learning. *The Internet and Higher Education, 14*(3), 158-163. https://doi.org/10.1016/j.iheduc.2011.04.001

López-Meneses, E. (2020). *Las tecnologías de la información y la comunicación en la Praxis Universitaria* [*Information and communication technologies in University Praxis*]. Octahedron Editions. https://doi.org/10.36006/16212

Luo, N., Li, H., Zhao, L., Wu, Z., & Zhang, J. (2021). Promoting student engagement in online learning through harmonious classroom environment. *The Asia-Pacific Education Researcher, 31*, 541-551. https://doi.org/10.1007/s40299-021-00606-5

Luo, N., Zhang, M., & Qi, D. (2017). Effects of different interactions on students' sense of community in e-learning environment. *Computers & Education, 115*, 153-160. https://doi.org/10.1016/j.compedu.2017.08.006

Magnani, S. V., Carmona, C., Agreda, N. H., & Shuali, T. (2019). El impacto de las estancias internacionales en el desarrollo de competencias en estudiantes de doctorado y su transferencia en diversos contextos [The impact of international stays on the development of skills in doctoral students and their transfer in various contexts]. *Revista Publicaciones* [*Magazine Publications*]*, 49*(1), 79-91. https://doi.org/10.30827/publicaciones.v49i1.9854

Major, C. (2020). Collaborative learning: A tried and true active learning method for the college classroom. *New Directions for Teaching and Learning, 164*, 19-28 https://doi.org/10.1002/tl.20420

Makridakis, S. (2017). The forthcoming artificial intelligence (AI) revolution: Its impact on society and firms. *Futures, 90*, 46-60. https://doi.org/10.1016/j.futures.2017.03.006

Marchi, B., Zanoni, S., & Jaber, M. Y. (2019). Economic production quantity model with learning in production, quality, reliability and energy efficiency. *Computers & Industrial Engineering, 129*, 502-511. https://doi.org/10.1016/j.cie.2019.02.009

McGuinness, C., & Fulton, C. (2019). Digital literacy in higher education: A case study of student engagement with e-tutorials using blended learning. *Journal of Information Technology Education: Innovations in Practice, 18*, 1-28. https://doi.org/10.28945/4190

Mehr, H. S., Zoghi, M., & Assadi, N. (2013). Effects of synchronous computer-mediated communication and face-to-face interaction on speaking skill development of Iranian EFL learners. *International Journal of Applied Linguistics & English Literature, 2*(5), 36-41. https://doi.org/10.7575/aiac.ijalel.v.2n.5p.36

Mitchell, A., & Vaughan, A. G. (2022). Implementing team-based learning: Findings from a database class. *Journal of Information Technology Education: Innovations in Practice, 21*, 1. https://doi.org/10.28945/4903

Molinillo, S., Aguilar, R., Anaya, R., & Vallespín, M. (2018). Exploring the impacts of interactions, social presence and emotional engagement on active collaborative learning in a social web-based environment. *Computers & Education, 123*, 41-52. https://doi.org/10.1016/j.compedu.2018.04.012

Mustakim, M., Trisnaningsih, T., & Adha, M. M. (2021). The effectiveness of online collaborative learning during COVID-19 pandemic. In *Proceedings of the Advances in Social Science, Education and Humanities Research: 4th Sriwijaya University Learning and Education International Conference* (pp. 256-262). Atlantis Press. https://doi.org/10.2991/assehr.k.201230.115

Muukkonen, H., Lakkala, M., Ilomäki, L., & Toom, A. (2022). Juxtaposing generic skills development in collaborative knowledge work competences and related pedagogical practices in higher education. *Frontiers in Education, 7*. https://doi.org/10.3389/feduc.2022.886726

Mykytiuk, S., Lysytska, O., Melnikova, T., & Mykytiuk, S. (2022). Facebook as a flexible ubiquitous learning space for developing speaking skills. *IAFOR Journal of Education, 10*(1), 109-133. https://doi.org/10.22492/ije.10.1.06

Myllykoski-Laine, S., Lahdenperä, J., Nikander, L., & Postareff, L. (2022). Students' experiences of the development of generic competences in the Finnish higher education context–The role of the teaching-learning environment and approaches to learning. *European Journal of Higher Education*, 1-20. https://doi.org/10.1080/21568235.2022.2058975

Natsis, A., Papadopoulos, P. M., & Obwegeser, N. (2018). Research integration in information systems education: Students' perceptions on learning strategies, skill development, and performance. *Journal of Information Technology Education Research, 17*, 345. https://doi.org/10.28945/4120

Negrete-Cortés, A. J., García-Gomar, M. L., & Fernández-Ruiz, P. A. (2020). Sincronía materna asociada al rendimiento académico en niños en edad escolar [Maternal synchrony associated with academic performance in school-age children]. *Revista Argentina de Ciencias del Comportamiento* [*Argentine Journal of Behavioral Sciences*]*, 12*(1), 60-71. https://doi.org/10.32348/1852.4206.v12.n1.25311

Nelwati, Abdullah, K. L., Chong, M. C., & McKenna, L. (2020). The effect of peer learning on professional competence development among Indonesian undergraduate nursing students: A quasi-experimental study. *Journal of Professional Nursing: Official Journal of the American Association of Colleges of Nursing, 36*(6), 477-483. https://doi.org/10.1016/j.profnurs.2020.03.008

Pastora, B., & Fuentes, A. (2021). La planificación de estrategias de enseñanza en un entorno virtual de aprendizaje [Planning teaching strategies in a virtual learning environment]. *Revista Científica UISRAEL* [*UISRAEL Scientific Magazine*]*, 8*(1), 59-76. https://doi.org/10.35290/rcui.v8n1.2021.341

Pereira, S. W., Fishman, E. K., & Rowe, S. P. (2022). The future is now: How technology and entertainment are transforming education in the artificial intelligence era. *Journal of the American College of Radiology, 19*(9), 1077-1078. https://doi.org/10.1016/j.jacr.2022.06.015

Pulgar, J., Ramírez, D., Umanzor, A., Candia, C., & Sánchez, I. (2022). Long-term collaboration with strong friendship ties improves academic performance in remote and hybrid teaching modalities in high school physics. *Physical Review Physics Education Research, 18*(1), 010146. https://doi.org/10.1103/physrevphyseducres.18.010146

Rui, Z., & Ying-Yan, W. (2012). Research of personalized web-based intelligent collaborative learning. *Journal of Software, 7*(4), 904-912. https://doi.org/10.4304/jsw.7.4.904-912

Safta-Zecheria, L., Stefaniga, S., Negru, I. A., Virag, F., & Mărgineanu, A. (2021). Collaborative learning in an action research project responding to challenges of online education during the COVID-19 pandemic. *Journal of Pedagogy/Revista de Pedagogie, 1*, 7-29. https://doi.org/10.26755/revped/2021.1/7

Sáiz-Manzanares, M., Martin, C., Alonso-Martínez, L., & Almeida, L. (2021). Usefulness of digital game-based learning in nursing and occupational therapy degrees: A comparative study at the University of Burgos. *International Journal of Environmental Research and Public Health, 18*(22), 11757. https://doi.org/10.3390/ijerph182211757

Sánchez, I. R., Herrera, E. C., & Rodríguez, C. E. (2020). Eficacia de resolución colaborativa de problemas en el desarrollo de habilidades cognitivo lingüísticas y en el rendimiento académico en física [Efficiency of collaborative problem solving in the development of cognitive-language skills and academic performance in physics]. *Formación Universitaria* [*University Education*]*, 13*(6), 191-204. https://doi.org/10.4067/S0718-50062020000600191

Schemmer, M., Hemmer, P., Nitsche, M. Niklas, K., & Vossing, M. (2022). A meta-analysis of the utility of explainable artificial intelligence in human-ai decision-making. In *Proceedings of the 2022 AAAI/ACM Conference on AI, Ethics, and Society* (pp. 617-626). ACM. https://doi.org/10.1145/3514094.3534128

Shafipour, R., Baten, R. A., Hasan, M. K., Ghoshal, G., Mateos, G., & Hoque, M. E. (2018). Buildup of speaking skills in an online learning community: A network-analytic exploration. *Palgrave Communications, 4*(1), 1-10. https://doi.org/10.1057/s41599-018-0116-6

Singh, J., Steele, K. & Singh, L. (2021). Combining the best of online and face-to-face learning: Hybrid and blended learning approach for COVID-19, post vaccine, & post-pandemic world. *Journal of Educational Technology Systems, 50*(2). https://doi.org/10.1177/00472395211047865

UI Haq, I., Anwar, A., Basharat, I., & Sultan, K. (2020). Intelligent tutoring supported collaborative learning (ITSCL): A hybrid framework. *International Journal of Advanced Computer Science and Applications, 11*(8), 523-535. https://doi.org/10.14569/ijacsa.2020.0110866

Wang, W., & Siau, K. (2019). Artificial intelligence, machine learning, automation, robotics, future of work and future of humanity: A review and research agenda. *Journal of Database Management, 30*(1), 61-79. https://doi.org/10.4018/jdm.2019010104

Webber, K. L., & Zheng, H. (2020). Data analytics and the imperatives for data-informed decision-making in higher education. In K. L. Webber, & H. Y. Zheng (Eds.), *Big data on campus: Data analytics and decision making in higher education* (pp.3-29). Johns Hopkins University Press.

Werner, K., & Woessmann, L. (2021). Will the COVID-19 pandemic leave a lasting legacy in children's skill development? *CESifo Forum, 22*(6), 33-40.

Wong, F. M., Kan, C. W., & Chow, S. K. (2022). From resistance to acceptance in small group work: Students' narratives. *Nurse Education Today, 111*, 105317. https://doi.org/10.1016/j.nedt.2022.105317

Yong, T., Wei, Y., Hongzhi, W., Can, W., Qiang, G., Tianjing, W., & Yanhao, H. (2022). Artificial intelligence techniques for power grid simulation analysis and decision making. In *Proceedings of the Chinese Society of Electrical Engineering*. https://doi.org/10.13334/j.0258-8013.pcsee.220015

Yucel, U., & Usluel, Y. (2016). Knowledge building and the quantity, content and quality of the interaction and participation of students in an online collaborative learning environment. *Computers & Education, 97*, 31-48. https://doi.org/10.1016/j.compedu.2016.02.015

Zhang, Q., Lin, S., Liu, J., & Zhang, J. (2021). Role of college environment on students' soft skills: Achievement goal structure. *College Teaching, 70*(4), 422-432. https://doi.org/10.1080/87567555.2021.1971603

Zhipeng, Z., Xuesong, G., Ting, L., & Chwee, L. (2022). Language learners' emotion regulation and enjoyment in an online collaborative writing program. *Studies in Second Language Learning and Teaching, 12*(3), 459-481. https://doi.org/10.14746/ssllt.2022.12.3.6