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The Cohesion of Small Groups in Technology-Mediated Learning Environments: A Systematic Literature Review

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Abstract

The development of group cohesion for small groups in face-to-face educational learning settings has been widely studied for decades. The calibre of group cohesion within these contexts is typically associated with increases in performance, resulting in a productive collaboration that helps drive knowledge building and innovation within a learning environment. However, understanding and measuring cohesion in technology-mediated learning experiences still requires additional research. This paper reports on a systematic literature review of small groups in technology-mediated learning settings to explore the definitions of cohesion and the methodologies used for the measurements that have been identified arising in this area. Furthermore, the review provides a characterisation of the factors that impact collaborative learning in computer supported environments, highlighting two important aspects: i) there is a significant gap in measuring cohesion using unobtrusive methods, such as relying on log or trace data and ii) there is a lack of longitudinal approaches to understand the emergence of cohesion. Finally, we discuss implications for future research in studying group cohesion.

Keywords: Higher Education, Technology-Mediated Learning, Collaboration, Group Cohesion, Small Groups

1. Introduction

It is becoming increasingly important to understand how collaborative processes, such as group cohesion, unfold in multi and interdisciplinary teams. Changing nature of work requires technologically literate and collaborative-ready workforce (Bakhshi et al., 2017; Hajkowicz et al., 2016). The COVID-19 global pandemic is an example of how abruptly organisations were forced to transition to novel models of manufacturing that assumed working remotely and in the conditions of restricted mobility (Bonaccorsi et al., 2020; Forum, 2020). The 'work from home' experiment due to the pandemic had a profound impact on the responsibility of the worker in the way they conducted virtual collaboration, such as handling personal obligations, spending more time coordinating and remaining optimistic that the culture of companies is changing for the better (PwC, 2020). Consequences of these changes have drastically impacted the norms of work, by driving the workforce to rapidly upskill or operate in environments that often represent drastic departure from what was accepted as a norm. With these current trends, the organisational landscapes are transforming due to emerging technologies and require organisations to anticipate

the shifting behaviours of stakeholders and technologies to remain competitive (Parry & Battista, 2019; Verhoef et al., 2021). Changes include becoming more diverse and inclusive, adopting more flexible work practices and becoming less hierarchical (Spurk & Straub, 2020; Waizenegger et al., 2020). In that sense, teamwork and collaboration will be increasingly valued, whereas innovation within firms and across industries becomes essential to improving productivity and competitiveness.

One of the vital factors that impacts the effectiveness of teams is group cohesion. It is commonly defined as the social bonding of members through the exchange and shared task commitment as a collective to achieve their goals (Miyake & Kirschner, 2014, p. 428). Group cohesion of small groups within collaborative environments is crucial for successful teams, as it fosters the development of trust, knowledge and ideas to effectively solve problems (Beal et al., 2003; Salas et al., 2005; Shaw, 1981; Wu et al., 2019). Current research almost unequivocally shows that highly cohesive teams have higher productivity and performance than teams with lower cohesion levels (Rogers & Lea, 2004; Salas et al., 2015; Williams et al., 2006). Cohesion unites and interlinks members of a group to form bonds and a sense of belonging (Shaw, 1981). Strongly bonded teams positively impact the members' morale, satisfaction, and motivation (Beal et al., 2003; Dewiyanti et al., 2007; Salas et al., 2005). It is asserted that effective teamwork cannot occur if groups are not cohesive, no matter the skill level that each team member may possess (Salas et al., 2015). In collaborative learning, cohesion in small groups tends to lead to the development of the greater trust in sharing ideas and information that further promotes learning(Edmondson, 1999; Kreijns et al., 2003; Williams et al., 2006). However, facilitating cohesion in technology-mediated contexts is argued to be challenging compared to face-to-face settings, primarily due to the absence of social cues to help forecast behaviour. As a result, this may impact the way cohesion is established and maintained (Gonzales et al., 2010; Kreijns et al., 2003; Shin & Song, 2011). Therefore, innovative approaches and strategies must be sought to identify and understand how groups or teams can enhance their cohesion in technology-mediated environments.

Given the importance of group and team cohesion in general, and technology-mediated environments, a systematic literature review was conducted to understand how cohesion is defined, measured, facilitated and impacts learners studying in collaborative settings. To achieve this review’s goal, articles were reviewed that measured and facilitated cohesion, such as the

design of technological tools and interventions that aim to improve cohesion and collaborative learning validated with surveys or log data. Second, a methodology is adopted and framed to understand how group cohesion is conceptualised, measured and analysed. Third, the findings are discussed regarding the methodologies used and the factors that influence or substantiate cohesion, learning performance and the progression of research. Finally, the knowledge gaps are discussed and the design implications and future work required for further development are addressed.

2. Background

2.1. Group Cohesion in Educational Context

Previous systematic reviews in technology-mediated collaborative learning have mainly reviewed social interactions between small groups that are important for group cohesion. For instance, Kreijns et al. (2003) undertook a review to explain the potential pitfalls of social interactions in technology-mediated collaborative learning, cautioning the notion that technologies enabling communication are not necessarily an incentive for interaction between members of a group. Goodyear et al. (2014), examine literature assessing diverse group processes emerging from various synchronous and asynchronous interactions, in fully face-to-face as well as blended face-to-face and remote settings. Similarly, reviews by Dado and Bodemer (2017) and Jahnq (2012), show the limitations of the existing research that relies on social network analysis methodologies in studying interactions in computer-supported collaborative learning. Another noteworthy review involved a meta-synthesis undertaken by Cherney et al. (2018), which examined literature concerning the small group interaction processes of collaboration in online learning environments, finding interdisciplinary issues across studies such as concepts and methodological approaches. Although social interactions in general, and small groups in particular, have been studied extensively across various settings, existing research is not conclusive how group cohesion can be defined. Moreover, it is unclear what are the commonly used methods used to measure group cohesion. Finally, there is a lack of understanding how group cohesion emerges and what is the association between various levels of group cohesion and outcomes of collaborative learning.

Literature concerning group cohesion in online learning communities, i.e. learners in large groups, has been extensively studied through the community of inquiry (CoI) framework

(Garrison & Arbaugh, 2007; Jan et al., 2019; Kreijns et al., 2014). However, learners in large online communities are typically defined differently compared to small groups, in the sense that they involve a community as a whole within a course without restriction to group size. Although, studies involving learning communities of small groups through the CoI framework exist, they are limited in number (Cherney et al., 2018). The distinguishment between small groups and large learning communities is essential as research shows that small groups are likely to have increased accountability, interrelationships, flexibility, contributions and dialogue than larger groups (Fay et al., 2000; Levine & Moreland, 1990). For instance, small groups consist of no less than two members and can range up to ten or more members, where communities can involve hundreds of members. While choosing the optimal number of members is situationally dependant, it is necessary to consider that the larger the group, the more organisationally complex it becomes and impacts performance (Levine & Moreland, 1990; Wheelan, 2009). Therefore, managing the size of groups is crucial and can avoid further issues of counterproductive behaviours such as parasitism, social loafing or misuse of resources (Aubé et al., 2011).

2.2. Group Cohesion in Organisational Context

The challenging aspect of reviewing small groups' cohesion in technology-mediated learning environments is formulating a suitable method supported by an existing methodology, such as the definitions used in coding steps present in research studies. To address this challenge, the concepts used in contemporary literature are drawn to help code this review.

2.2.1. Conceptualisation of Group Cohesion

Multiple studies in organisational literature such as sports, military, professional work and education have been conducted to analyse the cohesion of small groups (Chang & Bordia, 2001; Salas et al., 2015). Moreover, decades of research in this space have conceptualised group cohesion differently, such as unidimensional, e.g. members' attraction to the group or resistance to leaving (Seashore, 1954); or multidimensional, e.g. the sum of forces acting on members to remain in a group (Festinger, 1950). Based on existing reviews, the typical findings show that group cohesion is conceptualised as multidimensional and to a lesser extent, unidimensional (Cota et al., 1995; Salas et al., 2015). Conceptualisations of group cohesion are needed to understand the key concepts and dimensions involved. This unification allows potential cross-study comparisons to increase research conclusions and researchers' effectiveness to identify

standard metrics to enhance them and be effectively measured (Salas et al., 2015). Researchers in this area seek effective conceptualisations and the resulting dimensions with the most significant relationships with performance.

2.2.2. Data Sources of Group Cohesion

The primary data collection methods for group cohesion studies in other domains than technology-mediated collaborative learning are surveys, such as self-reported questionnaires. Surveys are flexible, cost-effective, and generalisable, allowing researchers to understand a given population's broad characteristics to ensure construct validity (Shaughnessy et al., 2000). Surveys provide practical means in understanding behaviours and attitudes by assessing group cohesion. Such surveys utilise different measures to evaluate specific dimensions of cohesion, such as their task or social aspects (Carron et al., 1985; Carron & Brawley, 2012). However, they hinder the participant from performing in their work by forcing them to take time to answer questions. Furthermore, surveys are also challenging as they run the risk of exposure to personal biases (Shaughnessy et al., 2000). To address these issues, unobtrusive methods have been recommended as an alternative research methodology to study group cohesion (Altebarmakian & Alterman, 2019a; Salas et al., 2015). These methods include accessing log data or live records collected from digital devices and systems. For example, the collection of learning traces collected by learning management systems (Dobre, 2015; Schwendimann et al., 2016) or more recently, physiological behaviours and synchrony of eye gazing, body language, heart rate and brainwave data of members within a group (Gordon et al., 2020; D. Guo et al., 2019; Spikol et al., 2018; X. Yang et al., 2020). Similar studies can help gather a deeper understanding of how physiological components can impact group cohesion. However, Salas et al. (2015) argue that valid unobtrusive indicators of cohesion must use theoretical underpinnings in the science of assessment to promote generalisation. This approach will ensure that studies can be repeated using the same process to gain further insights and advance research.

2.2.3. Dimensions of Cohesion

In the review of team cohesion measures by Salas et al. (2015), the authors identified the five most common dimensions of group cohesion and performance-related studies, namely (1) task cohesion, (2) social cohesion, (3) belongingness, (4) group pride and (5) morale. **Task cohesion** is commonly defined as the pull that keeps members together through a shared obligation to realise their ambitions and targets (Carron et al., 1985). Enhanced task cohesion levels are essential to a group's performance in reaching their objectives, such as being receptive to

feedback and working towards a common strategy to achieve a goal. **Social cohesion** refers to the level of connectedness between members of the group based on their social interactions within a given environment (Carron et al., 1985). As shown by past research, higher levels of social interactions can increase and maintain positive relationships within the group. **Belongingness** is a dimension representing the degree of group members' sense of position within the group (Shaw, 1981). This vital dimension is crucial for human emotional needs, such as feeling accepted and included in a group. **Group pride** is the level of fondness for the state or principles that the group's exhibit, such as the sense of the importance of being a member (Beal et al., 2003). Lastly, the **Morale** dimension represents the level of devotion and endurance of each group member to remain within the group (Cartwright & Zander, 1960). Loyalty is crucial as it stands for commitment and trust. As a result, it allows members of a group to trust each other and be willing to take risks to achieve greater rewards. This review explores how these dimensions are considered by researchers studying group cohesion of small groups in collaborative learning platforms.

2.2.4. Measures and Analysis of Cohesion

To analyse group cohesion dimensions, researchers often measure cohesion at the individual, team or mixed level (Salas et al., 2015). The primary focus of the measurements and analysis of cohesion is primarily dependent on survey-based studies. For instance, self-reports are often used to capture an individual reflecting about themselves in the group or by reflecting on their team members (Salas et al., 2015). In terms of the level of analysis, inferential statistical approaches driven by theoretical group cohesion metrics are used to analyse cohesion by calculating the average across all participants (individual) or aggregating each group and then calculating the average across those groups (team). This procedure allows for a practical synthesis towards understanding how researchers measure and analyse group cohesion (Salas et al., 2015). Specifically, an important focus of measurement identifies and analyses members' attitudes and behaviours within a group. Attitudes can relate to the sentiment of a member and their self-reflection or view of their group (Galyon et al., 2016), and the behaviours can involve participating within the group socialising outside professional environments as an example (Chen & You, 2019; Gupta & Bakker, 2020).

Grounded and motivated in the approaches from the organisational sciences that have defined, conceptualised, collected and analysed the dimensions of cohesion based on Salas et al. (2015)

review, this systematic review is framed similarly that caters towards our research questions. In the review, research focusing on collaborative learning through technology-mediated environments of small groups are examined based on the adopted framework to understand the definitions, methodological approaches and factors that impact and facilitate group cohesion in these environments.

3. Research Questions

The review investigates the research methods and trajectory of group cohesion literature of small groups in technology-mediated environments. To address these aims, the following research questions are posed:

Research Question 1: What are the most commonly utilised definitions of group cohesion in in technology-mediated learning setting?

Research Question 2: What methodological approaches are commonly used to measure and analyse group cohesion of learners in technology-mediated environments?

Research Question 3: What factors impact and facilitate group cohesion in technology-mediated environments?

First, how cohesion is conceptualised similarly to the contemporary literature framed under Salas et al. (2015) is explored. Next, the measures and types of analysis that are utilised for group cohesion to provide an overview of current methodological approaches are examined. Then the emerging factors related to group cohesion, to provide the synthesis of the current state of literature around group cohesion in technology-mediated environments are explored. Subsequently, the knowledge gaps and challenges in this area are also examined. Finally, the summary of findings will then be discussed to understand the methodological approaches, impacts on collaborative learning, research progression, and future design facilitation.

4. Method

4.1. Literature Search and Inclusion Criteria

The systematic literature review procedure was split into 4 phases: 1) Identification, 2)

Screening, 3) Eligibility, and 4) Inclusion, as shown in Fig 1 following the PRISMA framework (Moher et al., 2009). The first phase involved a systematic search between 1995 to 2020 (inclusive) to derive the existing literature review. In 1995, the first international bi-annual conference for computer-supported collaborative learning (CSCL) research took place (Stahl & Hesse, 2006), and is known to be the first official source of literature related to collaborative learning incorporating technologies. Therefore, literature from that point onwards was used as a reference for the systematic review. Generic search terms such as:

> *ALL = (" computer-supported collaborative learning" OR" online learning*" OR "distance learning") AND ALL = (" group cohesi*" OR" team cohesi*")*

were used in the following databases: Scopus, Springer, Taylor and Francis, Science Direct, Wiley, Web of Science, Emerald, ACM and IEEE. Peer-reviewed papers were included if (a) group or team cohesion was a focal point, (b) they facilitated group cohesion in a technology-mediated learning environment and (c) they used methods to evaluate group cohesion that has implications for learning. The review was limited to papers exploring cohesion in K-12 and higher education. Furthermore, extensive but constrained searches were required to ensure that the risk of missing quality papers is minimised. Specifically, the identification criteria included team cohesion studies to avoid excluding papers that have examined group cohesion within teams. There is a risk that studies may overlap these terms interchangeably in educational learning contexts. Therefore, those studies are included if they meet the inclusion criteria of this systematic review.

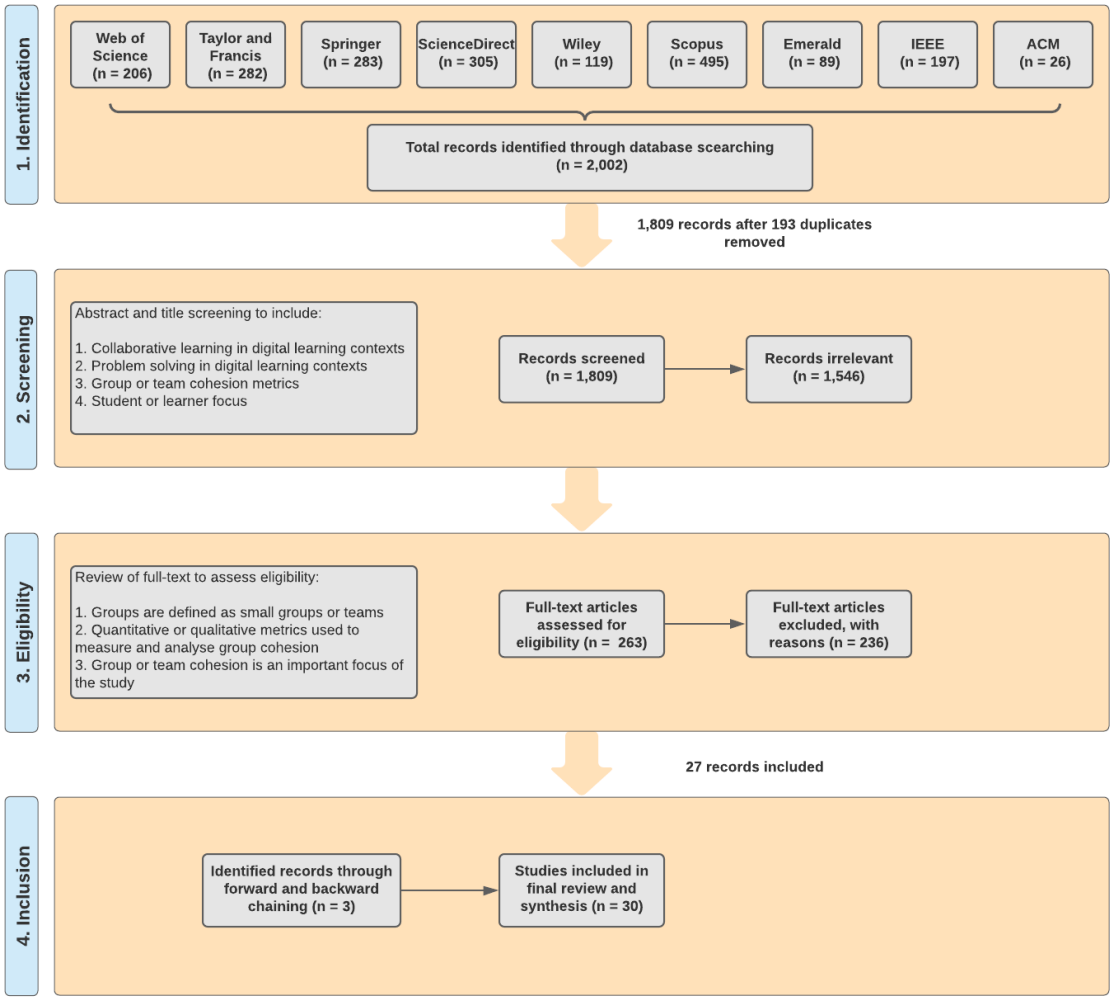


Fig. 1. Overview of the Systematic Literature Review Process

This search process resulted in 1,809 records following the removal of duplicates. After completing the search, the second phase involved screening the title and abstract using the Covidence systematic literature management tool (https://www.covidence.org/). Features of the tool were used, such as highlighting relevant keywords to streamline the screening process. For cases where the title and abstract descriptions did not indicate relevant papers, they were examined in detail by reading the methodology and results. Two reviewers coded 350 papers during this phase in 3 iterations, which resulted in the interrater agreement of 0.42, 0.63 and 0.88, respectively, using Cohen's Kappa (Cohen, 1960). At each iteration, conflicts were discussed and resolved until a substantial agreement with a Kappa of 0.80 or greater was achieved. A single reviewer coded the following 1,459 papers. In total, the screening procedure

resulted in 1,546 irrelevant papers. The third phase involved assessing the eligibility of 263 full-text articles. This process includes reading the papers in detail and selecting papers that align with the following inclusion criteria, where the study:

1) Presents original research, analysing group or team cohesion in technology-mediated learning environments
2) K-12 and higher education in technology-mediated environments that compromises of technology-mediated learning, i.e. computer-supported collaborative learning,
3) Was published in a peer-reviewed journal/conference proceeding, available in English,
4) Focused on quantitative, qualitative or a mixture of research methods to measure the dimensions of group cohesion (i.e. task or social cohesion),
5) Relies on log data, questionnaires or surveys used to validate or test cohesion and the study applies descriptive or inferential statistics and identifies findings that have implications for collaborative learning,
6) Includes only small groups, e.g. 2-10 members per group.

Following this procedure, 236 papers did not meet the selection criteria and were not considered for final extraction. The fourth and last step involved manual forward and backward chaining of papers selected (n = 27) to ensure that the risk of missing papers is minimised. This procedure resulted in the addition of 3 papers that met the screening and eligibility criteria. The final screening process resulted in 30 papers that satisfied the criteria for inclusion in this review.

The breadth of the search extended to conference papers, and the limited number of journal articles drove the decision to include them. If the conference papers were excluded, only a limited number of studies could be examined. The inclusion of conference papers is also strongly aligned to this review's themes, as they yield important information towards how researchers used novel approaches to link group cohesion with collaborative learning. Therefore, the decision was made to include them in the study. In the final stages of the systematic review, the selected 30 studies were critically appraised using the Joanna Briggs Institute (JBI) checklist with slight modifications to cater for the frame of reference for qualitative and quantitative research, cross-sectional and quasi-experimental accordingly (Lockwood et al., 2015; Moola et al., 2017; Tufanaru et al., 2017). All the selected studies were considered to be at minimum risk

of bias and were promptly extracted for review.

4.2. Analysis

Research questions were addressed by synthesising the 30 systematically selected studies shown in Appendix Tables A.1 and A.5. Predominantly, the systematic review aims to discern the definitions, measures and methods used to analyse group cohesion in technology-mediated environments and their impacts on small groups' collaborative learning. Each study was examined on how they measured cohesion (e.g. task cohesion, social cohesion, belongingness, group pride and morale), including the level of measurement and analysis used for individuals and teams. Moreover, the dimensions of cohesion were included to examine if they were conceptualised as unidimensional or multidimensional based on Seashore (1954) or Festinger (1950) definitions, respectively. The summary of the codes regarding cohesion measures such as the focus of measurement, analysis and conceptualisations can be found in Table 2. The codes were adopted and framed similarly from an existing literature review that measured team cohesion (Salas et al., 2015). The motivation for adopting a similar approach was two-fold: firstly, the need to establish a peer-reviewed approach to help code the results and; secondly, the coded metrics strongly aligns with the methodology to help answer the research questions. Thus, the papers were coded as part of the review using the adapted methodology, keeping the same definitions used in contemporary literature, concerning the inclusion criteria and research questions.

In addition to the adopted methodology, the review captures the methods that researchers commonly used to define and conduct the measurement and analysis of group cohesion, i.e. methods that were obtrusive, unobtrusive or mixed to understand how researchers use their methods. Further, the data collection formats researchers used, such as surveys, log data or a mixture of both, are also drawn. The study type, e.g. longitudinal, cross-sectional or design-based research and statistical approaches, to further understand how research is conducted were included in the literature. Furthermore, factors that had potential implications for group cohesion and whether they impact performance in technology-mediated collaborative learning were collected. These are categorised into factors (i.e. substantiating and influencing, see Fig 2) by synthesising them through cue-cards, comparing, contrasting and critically evaluating the selected literature. The study's generalisability, implications, and limitations were also coded and

examined to view the field's progression. The population and group sizes, along with the duration for each study, were recorded and summarised. Overall, the findings across the extracted literature were critically evaluated to conclude from the results. The workflow structure of the systematic review process can be seen in Fig 2.

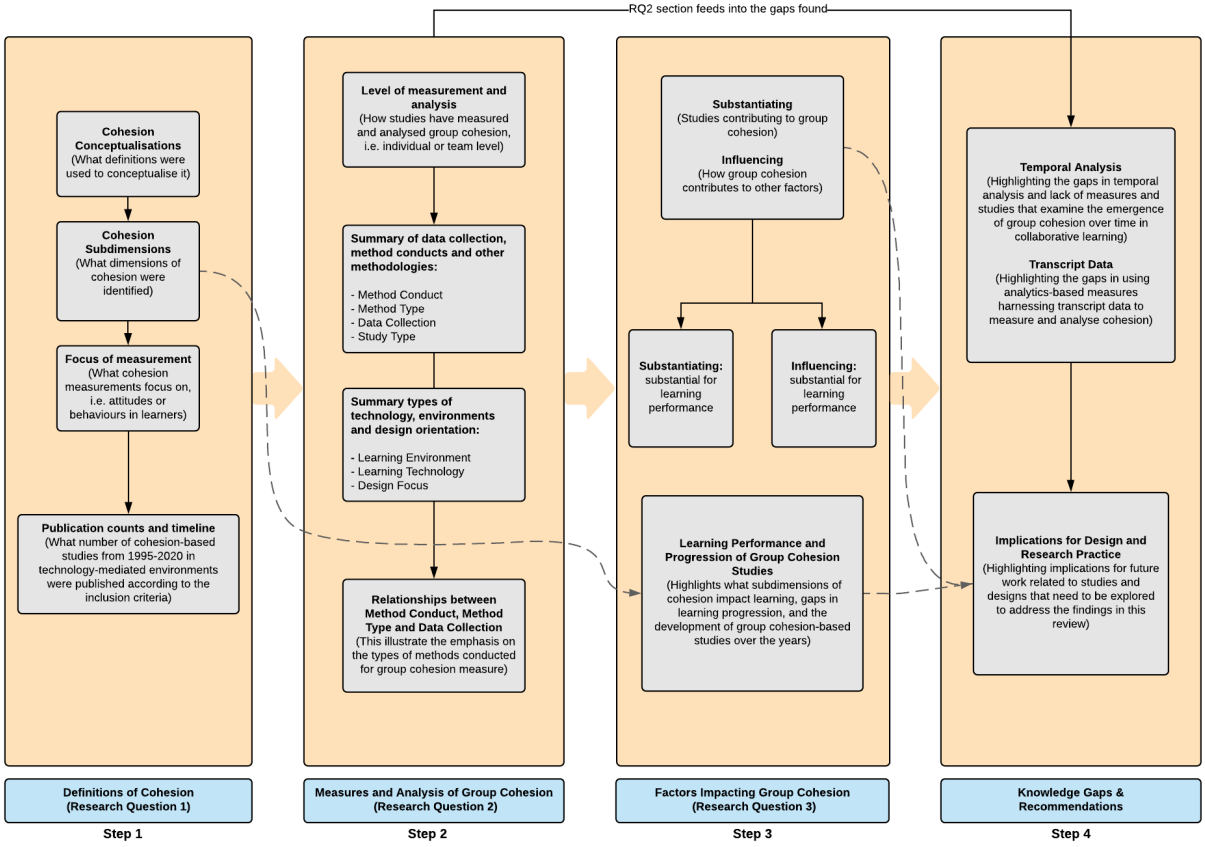


Fig. 2. Workflow of the Systematic Literature Review Structure and Processes

4.3. Limitations

In this review, the screening process presented challenges as numerous papers were considered to be studies of group cohesion following specific criteria, which they were not. For instance, studies often mentioned and discussed group cohesion, but had not explicitly conducted any study that analyses and measures it. In other words, the focus of those studies was not about group cohesion in general. Therefore, a rigorous process was required to carefully examine each paper that met the research objective and inclusion criteria that included studies focusing on group cohesion. The selected studies that were eventually included in this review presented

additional challenges in terms of the interpretations and the broader implications for group cohesion in technology-mediated learning environments. For example, the selected studies proved difficult in smoothly generalising contributions, as literature in this area is scarce. Some studies focused on various factors such as behavioural indicators that can negatively or positively impact group cohesion, whereas other studies included design aspects that help facilitate cohesion. The issue was addressed by categorising them into groups by understanding how each study contributed to cohesion and improved other aspects within a technology-mediated learning platform. This way, it provides us with a valuable contribution regarding how studies in this area have progressed over the years.

5. Results and Discussion

5.1. Summary of Selected Studies

Table 1 shows the type of publication, educational level, study period, group size and population in the selected studies (Appendix Table A.1). It can be observed from Fig 3 and Table 1 that the majority of the studies have been published in journals (69%) and a lesser extent, at conferences (31%). The papers published in journals and conferences from 2003 to 2020 seem to be equally spread over time. While the number of studies oscillated between 1 and 3 from 2010, there has been a noticeable growth starting from 2018. This growth may signify an increased interest in group cohesion studies. No papers from 1995 to 2002 met the inclusion criteria.

Table 1

Overview of the summarised studies containing publications and student population, group sizes and their duration of study.

Data Description	Publication	
	Count	%
Type of Publication		
Journal	20	67
Conference	10	33
Education Level		
University	30	100
K-12	0	0
Period of Study		
1-8 Weeks	8	27
10-16 Weeks	18	60
>16 Weeks	3	10
Unknown	1	3
Group Size		
2-10	1	3
3-5	14	47
4-6	11	37
5-7	4	13
Student Population		
0-25	2	7
25-50	9	30
50-100	7	23
100-200	7	23
200-450	5	17

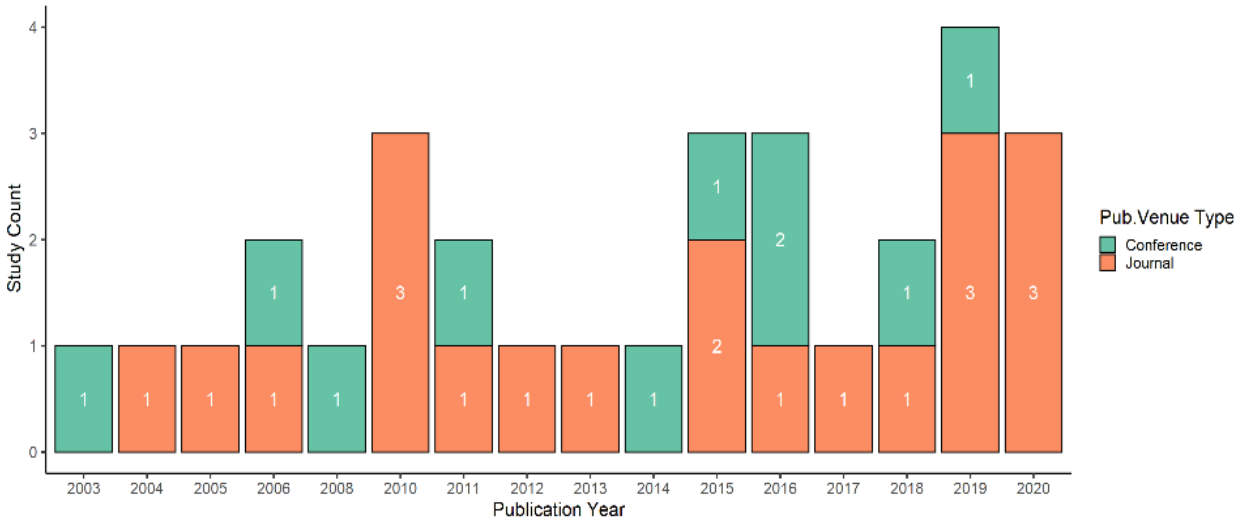


Fig. 3. The frequency of studies per year and which venue the papers were published

The educational level seen in Table 1, shows the selected studies predominantly consisting of students in higher education (100%) and less with K-12 education (0%). Moreover, we observe that a large portion of studies had students studying between 10 and 16 weeks (60%) and

between 1 and 8 weeks (27%), while studies that were over 16 weeks (10%) were less common. Group sizes were mostly between 3 to 5 (47%) students, with fewer studies containing 4 to 6 students (37%). The majority of studies had group sizes with smaller ranges (e.g. 3-5, 4-6 ,5-7), one study had group sizes ranging from 2 to 10 students (3%). Typical student population sizes ranged between 25 to 50 (30%), 50 to 100 (23%) and 100 to 200 (23%) in the selected studies. To a lesser extent, other studies contained between 0 and 25 students (7%) and also 200 to 450 (17%). All studies shown in the table were conducted in a university setting.

Fig 4 shows that most selected studies included students from Management, Education, Technology and Computer Sciences courses. The smallest number of studies involved students from Human Resources, Marketing, Mathematics, Language and Psychology. Interestingly, a significant portion of studies that involved Technology and Computer Science courses had been published to conferences. This finding is not surprising, as studies published within conferences frequently blend statistical methodologies with computer education that involve students studying technology or computer-based subjects.

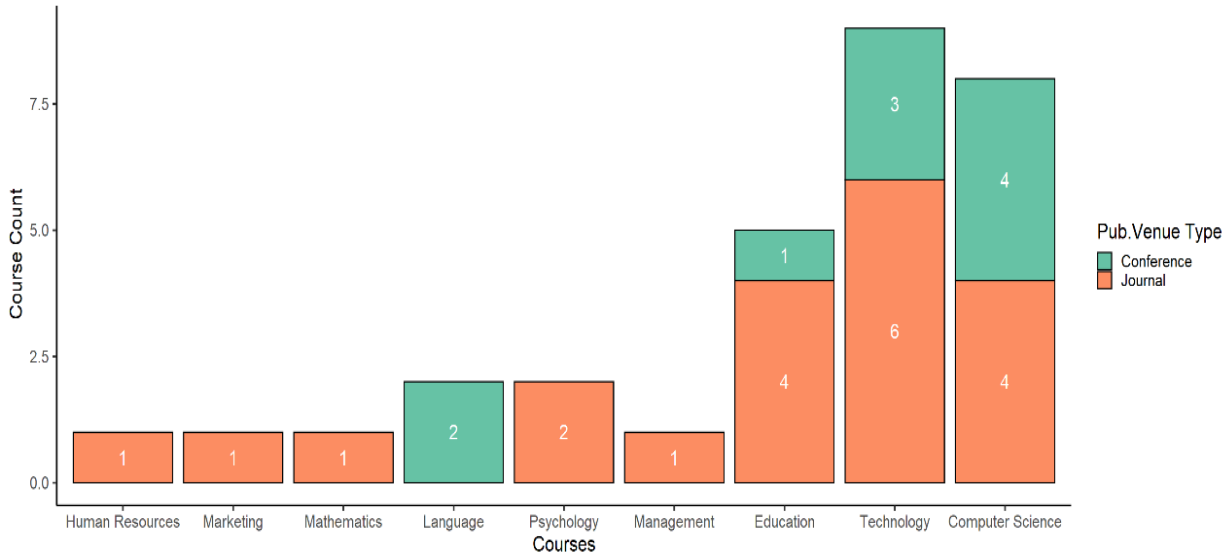


Fig. 4. The frequency of courses where group cohesion studies are undertaken and to which venue the papers were published

Looking at journals, the majority of studies involved students from Mathematics, Psychology, Management, Education and Technology related courses. Observing the student disciplinary areas, substantial heterogeneity based on the courses where researchers examined computer learning and group cohesion is seen.

The review also shows some striking results regarding the level of education under study. All studies included in the review focused on higher education, with none of the included studies analysing the K-12 context. Such disparity is a significant concern and demonstrates a gap in the literature for technology-mediated learning of small groups. Learners are increasingly developing 21st-Century skills in K-12 education, such as collaborative learning and problem-solving skills in environments driven by digital learning (Pellegrino, 2017). Developing these skills is important as examining group cohesion within these contexts is crucial towards understanding how small groups build relationships and work effectively. Future studies should examine K-12 education more closely to understand how cohesion develops in these contexts.

5.2. Definitions of Group Cohesion (Research Question 1)

To explore how group cohesion has been conceptualised, the adopted definitions of cohesion within the included studies were examined. Table 2 shows the group cohesion concepts, dimensions and the focus of measurement. The cohesion conceptualisation of the selected studies shows that (57%) are found to be multidimensional, (23%) unidimensional and (20%) as unknown. In Fig 5, it can be observed that the group cohesion concepts are becoming more multidimensional from 2015 and less unidimensional, indicating a shift from the latter. The findings confirm that this trend is also present within technology-mediated learning environments, signifying the increasing conceptualisation of the multidimensional concept for group cohesion studies (Chang & Bordia, 2001; Salas et al., 2015).

Table 2 also shows the task, social and belongingness dimensions of group cohesion were most widely used with (30%), (16%) and (32%) as seen in the table, respectively. However, group pride (2%) and morale (8%) dimensions are not widely studied in technology-mediated learning contexts. Besides the dimensions of cohesion, a mixture of attitudes and behaviours (53%) represented the most frequent focus of the included studies. The dimensions of group cohesion, mainly social, task and belongingness, have seen vested interest from 2015 and onwards in technology-mediated education. The findings show what researchers focus on regarding measurements of group cohesion. These results also show the increasing utilisation of these dimensions in the organisational literature, according to Salas et al. (2015) team cohesion review.

Table 2

The summary of definitions, dimensions and focus of measurement

Data Description	Publications	
	Count	%
Cohesion Conceptualisation		
Unidimensional	7	23
Multidimensional	17	57
Unknown	6	20
Group Cohesion Dimensions (n = 37)		
Task	11	30
Social	6	16
Belongingness	12	32
Group Pride	1	2
Morale	3	8
Unknown	4	12
Operationalisaton/focus of measurement		
Attitude	4	13
Behaviour	5	17
Mixed	16	53
Unknown	5	17

Note. n refers to the total number of dimensions found in the selected studies.

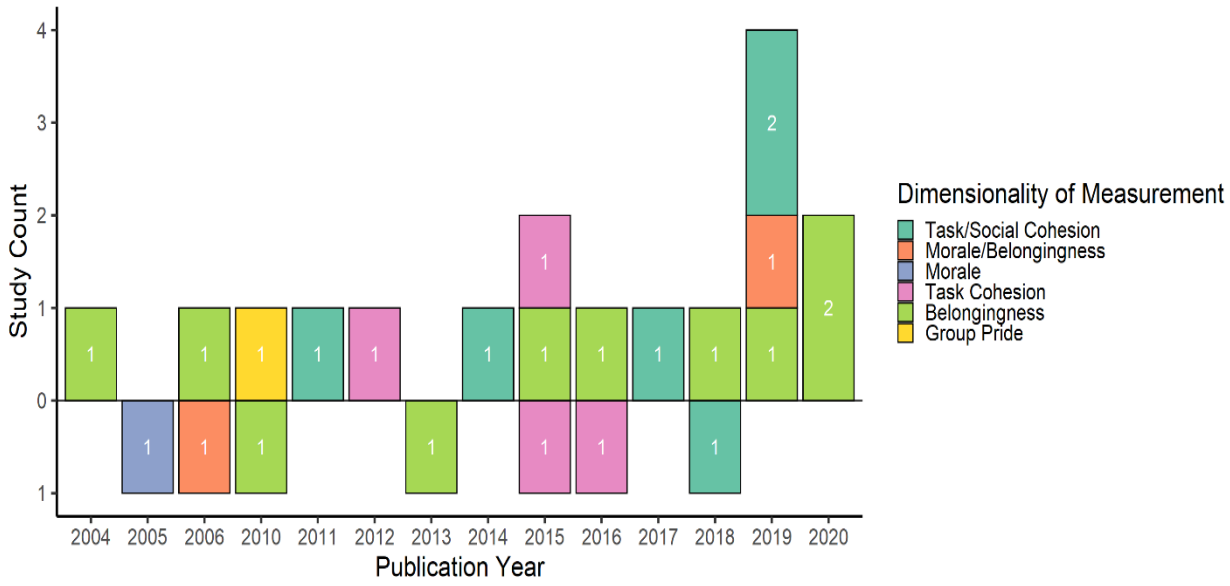


Fig. 5. The frequency and publication year of multidimensional (above the horizontal line) and unidimensional studies (below the horizontal line)

Besides the noticeable increases in the task and social dimensions in this review, the finding suggests considerable interest in measuring the emotional connections between individuals of a

team. An explanation for this phenomenon can be related to issues present in technology-mediated learning contexts, such as identification within the group, working in small groups, building trust, having accountability, increasing motivation, maintaining goals and the overall design of the learning environment (Bilgin & Gul, 2020; Hansen, 2016; Lu & Xie, 2018; Rogers & Lea, 2004; Tseng & Yeh, 2013; Williams et al., 2006; F. G. Yilmaz & Yilmaz, 2019). However, other dimensions, such as group pride and morale, are not extensively studied in the reviewed literature concerning technology-mediated learning. This finding also aligns with Salas et al. (2015) review, where these dimensions are also limited in other fields (i.e. sports, professional work, military and other organisational literature). Moreover, the existing studies primarily rely on survey data. The data shows only 1 out of 5 studies have been defined and conceptualised according to the dimensions noted in this review using log data. On the other hand, the four studies with a mixture of log and survey data have only been examined from the survey point of view and not from the learners trace logs. As a result, there is an obvious gap in the existing literature that would elaborate on the approaches to conceptualise and measure team cohesion using unobtrusive approaches, such as relying on log multimodal (e.g., sensors) data.

In terms of operationalisation/focus of measurement, the findings show that they are predominantly mixed, capturing learner's behaviour and attitudes in groups. Researchers tend to understand how both factors impact group cohesion. Attitudes are often associated with behaviours, and research shows that attitude is used to understand the relationship of future behaviours (Glasman & Albarracín, 2006). The existing researcher also explores what occurs in technology-mediated learning platforms relating to the learner's cohesion, such as the future motives and participation within a group and what group members think about their peers (Gupta & Bakker, 2020; S.-L. Wang & Hong, 2018; S.-L. Wang & Hwang, 2012; Zheng et al., 2014).

Based on the five common sub-dimensions identified by Salas et al. (2015) and the results of our review, the findings show that no studies have explored a combination of all five group cohesion dimensions (i.e., task cohesion, social cohesion, belongingness, morale and group pride). There are several instances where studies have paired task and social cohesion or belongingness and morale dimensions. For example, how dimensions of task and social cohesion are impacted by the roles, collective task value and socially shared regulated learning(S.-L. Wang & Hong, 2018; Zheng, 2017; Zheng et al., 2014) and how belongingness and morale impact self-regulation of learning (Xie et al., 2019) in collaborative groups. Conceptualising and

choosing the dimensions is dependent on the context of the research problem. For instance, whether the task at hand allows group members to express their belongingness to the group and how such information can be captured. Similar for other complex dimensions, such as group level of allegiance (group pride), their level of confidence (morale), synchrony and exchange (social cohesion), and their commitment to achieving the group's goals (task cohesion). Future studies in collaborative learning are encouraged to explore the relationship between the sub-dimensions and be aware of logistical challenges to facilitate them.

5.3. Measures and Analysis of Group Cohesion (Research Question 2)

Table 3

The summary levels of measurement and analysis for examining group cohesion

Data Description	Publications	
	Count	%
Level of Measurement		
Individual	5	17
Group	6	20
Mixed	19	63
Level of Analysis		
Individual	3	10
Group	17	56
Mixed	10	34

The results in Table 3 show the level of measurements for group cohesion studies in technology-mediated learning contexts is primarily mixed (63%), i.e. measuring both the individual and group. This finding suggests that researchers tend to adopt a multilevel view of cohesion for measurement. Moreover, the results show that the level of analysis occurs at the group (56%) and mixed-level (34%), while individual analysis (10%) is to a lesser extent. The findings in this review suggest that researchers who study group cohesion mainly measure aspects of both individual and group work as one package, then analyse based on the overall group using the statistical approaches outlined in Appendix Table A.5, to better understand attitudes and behaviours, as well as performance in collaborative learning. Similarly, Salas et al. (2015) review of team cohesion in organisational literature found that multilevel approaches yielded better results in cohesion-performance relationships and that the analysis of teams yielded more significant findings than any other composition. Overall, the reviewed literature shows consistency in valuing the idea that multilevel approaches effectively measure and analyse group cohesion.

Table 5

The summary of data collection, method conducts, design, and other research methodologies used in measuring and analysing group cohesion

Data Description	Publications	
	Count	%
Method Conduct		
Obtrusive	20	66
Unobtrusive	5	17
Mixed	5	17
Method Type		
Quantitative	25	84
Qualitative	1	3
Mixed	3	10
N/A	1	3
Data Collection		
Survey	20	67
Log (trace) data	5	17
Mixed	4	13
N/A	1	3
Study Type		
Longitudinal	2	7
Cross-sectional	26	86
Design Based-Research	2	7
Learning Environment		
Online	17	57
Blended	13	43
Learning Technology		
Learning Management System	24	80
Media Communication	4	13
Agent Based	2	7
Design Orientated		
Yes	9	30
No	21	70

Table 5 shows the research methodology commonly used for group cohesion studies in technology-mediated collaborative learning environments. The overview of these studies is seen in Appendix Table A.3 and A.5. The results show that the reviewed studies tend to adopt obtrusive (66%) and to a lesser extent, unobtrusive (5%) and mixed (5%) approaches to measure and analyse group cohesion. The type of methods surrounding the conducts are inherently quantitative (83%) and to a lesser extent, mixed, qualitative and quantitative (10%). Data collection methods are typically survey-based (66%) and mixed (14%). In contrast, log data

(17%) collection methodologies are not widely adopted in the contemporary literature. The study types are predominantly cross-sectional (86%) and, to a lesser extent, design based-research (7%) and longitudinal (7%).

The learning environments identified across the 30 selected studies in this review consist of blended learning (43%) and online learning (57%). The former considers students in a blend of collaborative face-to-face and computer-based learning technologies on and off campus. The latter considers collaborative learning through virtual, distance-based or delivery of education that is primarily online. Moreover, the learning technologies across these studies are mainly learning management systems (LMS) (80%), with media communication (13%) and agent-based learning (7%) to a lesser extent. The findings also show that only 30% of studies include a design-based technological implementation in conjunction with the measure and analysis of cohesion in the learning environment. Moreover, only 2 out of 30 studies have undertaken design-based research specifically facilitating a technological implementation to support and analyse group cohesion directly. The limited number of studies found indicates a clear gap where researchers have not focused on developing tools incorporated in the learning environment to help cohesion in collaborative learning contexts as part of design-based research iterations.



Fig. 6. The frequency of the extracted studies from the blended and online learning environments as seen on the y-axis compared to the dimensions of group cohesion (see Table 2) along the x-axis.

The existing literature measuring and analysing the dimensions of cohesion are relatively even between online (n = 17) and blended learning (n = 13) environments (see Fig 6). This finding indicates that researchers who measured group cohesion in either environment focus on similar cohesion dimensions (see Table 2). The rationale behind this notion is related to the

findings that all collaborative settings found in this review, regardless of the learning environment, are through learning technologies using computing devices, such as desktop, laptop or mobile. Overall, the relevance of such finding is an important one as it shows that the research interest of both environments is the same in this review.

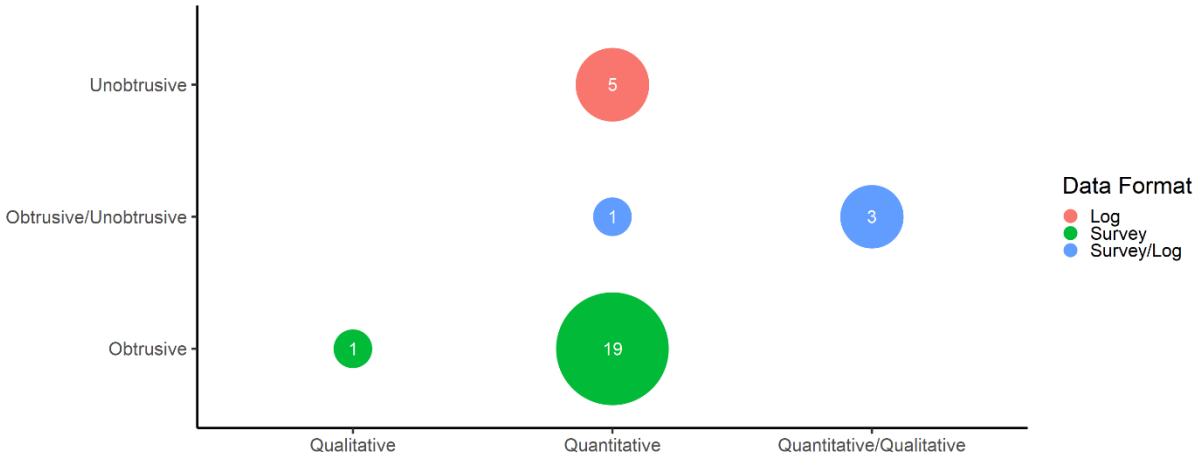


Fig. 7. The frequency of research methods, data formats and their association with research measures (i.e. obtrusive, unobtrusive or mixed-method conducts) applicable from the extracted results in Appendix Table A.4.

The additional results were gathered to observe the interrelations between method conduct, method type and data collection illustrated in Fig 7. The finding shows that out of the 29 reviewed studies, only three use qualitative and quantitative methods utilising survey and log data. The quantitative research methodologies represent the largest portion of the review studies (n = 25). As such, the data collection methodologies were largely survey-based (n = 20), whereas log data and mixed, (n = 5) and (n = 1) were to a lesser extent, respectively. The method conducts for log-driven data were unobtrusive (n = 5), while mixed conducts were a combination between survey and log data collection approaches (n = 4).

An important aspect of measuring group cohesion in this review includes understanding how the data drives the research. For example, considering the type of data, collection methods and the nature of use to understand group cohesion. Findings show that methodologies are mainly obtrusive due to the large number of surveys recorded in the reviewed studies (Beranek & Martz, 2005; Bilgin & Gul, 2020; David et al., 2006; Galyon et al., 2016; Garcia & Privado, 2020; D. Guo et al., 2019; Hansen, 2016; Lam, 2015; Rogers & Lea, 2004; Shin & Song, 2011; Tseng & Yeh, 2013; S.-L. Wang & Hong, 2018; S.-L. Wang & Hwang, 2012; Williams et al., 2006; F. G.

Yilmaz & Yilmaz, 2019; R. Yilmaz et al., 2020; Zheng, 2017; Zheng et al., 2014). The results suggest that quantitative research is the main methodology adopted to study group cohesion more than qualitative, as seen in Fig 6. Another interesting finding is that many studies are cross-sectional, e.g. studies taking place at a single point of time and examining specific variables. Studies, including longitudinal and design-based research are very few. However, to gain a more in-depth perspective, in Fig 6 the connections between the research methodologies are illustrated. The findings show that the selected literature regarding the utilisation of log and mixed data in quantitative-based research using unobtrusive approaches to measure group cohesion is limited in digitally enabled education. Similar issues are found in organisational literature regarding the limitations of studies that include log data and unobtrusive methods to understand the development of cohesion (Salas et al., 2015). This contribution is significant as there are clear gaps across some fields where researchers have not closely investigated cohesion using log data, e.g. trace data of teams, that examine their behavioural and cognitive actions using methods considered unobtrusive.

The dominant data collection methodologies to measure and analyse group cohesion are primarily quantitative-based surveys. Researchers use quantitative surveys such as Likert scaling to quantify group cohesion. Although, four unique articles found in the review had taken advantage of the data from student learning platforms and incorporated both survey and log data, where the latter had a mixture of data that was both quantitative and qualitative to measure group cohesion (Castro-Hernandez et al., 2015, 2016; Gonzales et al., 2010; Xie et al., 2019). However, no instances where the utilisation of log data such as student engagement was validated using a survey instrument to measure and analyse group cohesion. This finding shows a missed opportunity to help establish a link between how learner's behavioural and cognitive actions, including their communication within the group, can be used as an indicator to help understand the development and level of cohesion in these technology-mediated learning platforms. As such, exploratory studies need to be conducted to incorporate log data from LMS and adopt methodologies used in educational data mining (EDM) and learning analytics (LA) to establish how the learner's social and course engagement can indicate group cohesion in collaborative learning.

Survey data have been predominantly used to validate the static effects of cohesion, such as whether an intervention had improved group cohesion and group performance. However, a

caveat of surveys is their inability to address group cohesion processes with high fidelity. Surveys are inherently static and often not reliable measures (Kozlowski & Chao, 2012, p. 349, 2018, p. 580; Visser et al., 2000), as they are susceptible to a wide range of faults, such as coverage, sampling, nonresponse and measurement error described by Visser et al. (2000). Further, surveys interrupt continuous behaviours due to their obtrusive nature, such as forcing participants to stop and think while performing a task that may impact the way they answer the survey based on their current emotions and stress levels (Cook et al., 2002). As a result, surveys are substantially restricted in the way they capture the development of group cohesion as a process. Group cohesion is a dynamic state that fluctuates, reciprocates, or stabilises over time in groups or teams (Braun et al., 2020; Kozlowski & Chao, 2012). Understanding group cohesion as a process, requires different theoretical and methodological approaches relying on continuous streams of data. In this review, no selected studies had utilised or undertaken research examining group cohesion as a process that occurs in technology-mediated learning environments. Future research needs to facilitate studies that capture group cohesion processes and use measures to highlight the dynamic changes in these learning environments and their impacts on collaborative learning and performance.

Evaluating the dimensions of group cohesion through the choice of survey or log data is dependent on the context. For instance, using surveys to understand the effects or outcomes of an intervention for a control group in longitudinal or cross-sectional studies is a sound approach. On the other hand, using continuous streams of data, such as log data, is more suited to understand temporal aspects, such as how learning processes or group cohesion changes over time in dynamic environments (Knight et al., 2017; Visser et al., 2000). Preferably, employing both approaches are ideal for gaining a richer understanding of group cohesion if logistically possible (Salas et al., 2015).

5.4. Factors Impacting Group Cohesion (Research Question 3)

Table 6

The summary of identified factors that substantiates (contributes) to group cohesion and how group cohesion influences (impacts) other factors from the synthesised research

Data Description	Publications	
	Count	%
Substantiating	21	70
Social interaction	4	13

Linguistic style matching **	2	7
Gaming **	2	7
Shared identity	1	3
Group similarity	1	3
Teamwork orientation *	1	3
Collective efficacy *	1	3
Communication quality	1	3
Cohesion-based feedback	1	3
Socially shared regulated learning *	1	3
Mastery goals	1	3
Collective task value *	1	3
Roles	1	3
Metacognitive support	1	3
Engagement *	1	3
Participation	1	3
Influencing	5	17
Satisfaction	1	3
Leadership	1	3
Engagement *	1	3
Communication	1	3
Trust	1	3
Other	4	13

Note. * factors that are substantial for performance in collaborative learning

Table 6 shows the summary of the two most prominent factor groups, Substantiating (70%) and Influencing (17%), categorised from the selected studies in Appendix Table A.5. The Substantiating group concerns literature focusing on factors that have a considerable impact on group cohesion. In contrast, the Influencing group concerns literature where group cohesion impacts other factors in technology-mediated collaborative learning contexts. For example, the factor *Linguistics* shown in Table 6 was used to quantify group cohesion. The two (*) symbols indicate that (n = 2) studies had a substantial impact on collaborative learning based on the factor. In terms of the eloquent effects with performance in collaborative learning, 10 out of 30 studies presented the relationship. Other studies (n = 4) were unsuitable for fitting within the two constructed groups in the table. Investigating the selected review is an important contribution, as there is limited research investigating factors that either help substantiate cohesion and whether group cohesion impacts other factors in technology-mediated learning environments. The aim of this discussion critically reviews what knowledge has been generated over two decades in this area.

5.4.1. Substantiating

The findings of the Substantiating factors include a large selection of reviewed literature (*n* = 19) that examines how psychological factors impacted group cohesion in technology-mediated learning. The findings show an assortment of factors that are sparely used, with the exception of *social interactions* (*n* = 4), *linguistic style matching* (*n* = 2) and *gaming* (*n* = 2). It can be gleaned from Table 6 that communication and interaction aspects, such as networks, linguistics, communication and participation, have been used to quantify group cohesion (Castro-Hernandez et al., 2016; Galyon et al., 2016; Gonzales et al., 2010; Heo et al., 2010; Lam, 2015; Reffay et al., 2011; Reffay & Chanier, 2003; Y. Wang & Li, 2008). These factors are important and noteworthy as there is a strong connection between cohesion and social elements within groups that impact teams. Furthermore, the group's identification, orientation, and roles have also been explored to understand their impacts on cohesion (D. Guo et al., 2019; Rogers & Lea, 2004; Williams et al., 2006; Zheng et al., 2014). Further studies such as collective task value, socially shared regulated learning and metacognition are found to impact group cohesion substantially (S.-L. Wang & Hong, 2018; S.-L. Wang & Hwang, 2012; F. G. Yilmaz & Yilmaz, 2019; Zheng, 2017). Other interesting factors such as gamification, designs of online engagement, mastery goals and cohesion-based feedback in technology-mediated learning contexts to impact cohesion considerably (Altebarmakian & Alterman, 2019a, 2019b; Bilgin & Gul, 2020; Castro-Hernandez et al., 2015; Lu & Xie, 2018; Terzidou et al., 2016). Based on these findings, it can be observed that research regarding group cohesion-related studies in technology-mediated learning are very divergent and few. As a result, it is not clear to discern an agreeable conclusion that certain factors have more generalisability for effective group cohesion than others.

5.4.2. Influencing

The motivation for developing this factor group is to investigate how researchers examined the cohesion of small groups in digital learning environments that contributes to the overall collaborative learning. For instance, examining the consequences of group cohesion in collaborative environments impacts student’s learning. Based on the results, the Influencing group includes a small selection of reviewed literature (*n* = 5) that examined how group cohesion affects several factors in small groups' technology-mediated learning. A handful of factors such as satisfaction, leadership, communication, trust and engagement were examined in the reviewed

literature (Garcia & Privado, 2020; Hansen, 2016; Tseng & Yeh, 2013; Xie et al., 2019; R. Yilmaz et al., 2020). We highlight limited research investigating the benefits of group cohesion of small groups in digitally-driven collaborative learning environments due to the small number of studies found in the literature review. This finding is an important discovery as it demonstrates a knowledge gap to see the benefits of group cohesion in digitally-driven collaborative learning environments. For instance, in face-to-face learning environments, it has been established that group cohesion increases productivity, quality of ideas, friendships and many other skills. However, it is assumed that this holds for students in technology-mediated learning and that the same trends apply as seen in face-to-face environments. Consequently, the need to closely investigate and confirm that is the case and whether sufficient group cohesion in technology-driven platforms such as distance or online can build new skills not currently known in the literature. Further research is required to investigate and understand the consequence of group cohesion in technology-mediated learning environments that focus not only on performance indicators alone.

5.4.3. Learning Performance

An analysis to understand what factors are being associated with group performance was undertaken. The importance of such research aims to provide insights regarding factors that are known to increase the overall collaborative learning experience in technology-mediated contexts. Based on the 30 papers in the analysis identified, only ten had meaningful impacts on collaborative learning performance. The identified factors related to these studies are SSRL, engagement, gamification, teamwork orientation and linguistics (Altebarmakian & Alterman, 2019a; Bilgin & Gul, 2020; Castro-Hernandez et al., 2016; Gonzales et al., 2010; Terzidou et al., 2016; S.-L. Wang & Hong, 2018; S.-L. Wang & Hwang, 2012; Williams et al., 2006; Xie et al., 2019; Zheng, 2017). A commonality between the studies that show substance with collaborative learning outcomes have measured group cohesion as dimensions of task (n = 2), task/social (n = 3), belongingness (n = 3), belongingness/morale (n = 1) and group pride (n = 1). Only task cohesion, group pride and belongingness had an impact on collaborative learning performance. Interestingly, the findings show that social cohesion had no associations with collaborative learning outcomes. For example, high social cohesion can lead to lower academic results in collaborative groups (e.g. Castro-Hernandez et al., 2015; Heo et al., 2010; Zheng et al., 2014).

Recent studies in team learning by Dimes et al. (2021), found that if social cohesion is optimised with task cohesion (i.e. task cohesion is relatively higher than social cohesion), the team's learning is considerably better as opposed to one that is heavily one-sided. To facilitate effective design in future studies, researchers may consider developing collaborative learning environments that optimise or balance social and task interactions.

However, how these dimensions impact the progression of learning based on our review is unclear, as current methods heavily utilise static measures that focus on outcomes rather than behaviours or processes. For example, it is unknown how cohesion defined by dimensions (i.e. task or social cohesion) shown in Table 2 in groups emerges over time and impacts student's collaborative learning in technology-mediated environments.

5.5. Progression of Research

Recent trends of the reviewed studies show the use of learning analytic approaches, such as tracing learners' data from LMS to understand their behaviours in technology-mediated learning contexts (Siemens & Long, 2011). LA is used to understand and improve students' learning outcomes by measuring and collecting their trace data (Siemens & Long, 2011). For example, engagement data such as social communication and task activity are used as behavioural indicators to measure group cohesion of learner groups (Altebarmakian & Alterman, 2019a, 2019b; Xie et al., 2019; Zheng, 2017). A noteworthy study found in the reviewed literature by Altebarmakian and Alterman (2019b), has undertaken a design-based research study to understand group cohesion based on learner engagement in an online collaborative learning platform. Such studies are novel and essential in computer-supported collaborative learning literature, as they provide practical approaches to further understand the phenomena of collaborative learning in technology-mediated contexts through iterative designed-based research (Ludvigsen & Steier, 2019). Based on the trends, it is increasingly seen that behavioural indicators for group cohesion are becoming more critical in technology-mediated learning contexts. However, the rate at which this occurs, including the quantity and quality of studies produced, is somewhat limited in group cohesion studies from the review.

6. Knowledge Gaps and Recommendations

6.1. Temporal Analysis

In teams, cohesion is an emergent process that develops over time and is a useful indicator of team characterisation (Kozlowski & Chao, 2012; Marks et al., 2001). Applying a temporal approach is one way to help reveal the journey of how group cohesion develops, including the learning processes and factors impact them in technology-mediated learning contexts (Knight et al., 2017). The systematic analysis has revealed an interesting observation from the analysis was the lack of longitudinal studies from the reviewed literature (*n = 2*). This lack of temporal cohesion based studies seems to be prevalent in organisational domains as well (Salas et al., 2015). However, this systematic review revealed that logistical constraints in technology-mediated learning contexts, e.g. learning platforms, have fewer obstacles regarding the retrieval and quality of data than other settings where data collection is not possible (Lonn & Teasley, 2009; Romero et al., 2008). Learning platforms capture and store the footprints of learners in log data, which often contain temporal information, such as timestamps and events. Data from learning platforms are frequently analysed in LA using analytical strategies to understand learner behaviour and provide pedagogical support (Siemens & Long, 2011). The review has also shown that the selected studies have not utilised this capability to the full extent. For instance, the two longitudinal studies by Guo et al. (2010), Rogers and Lea (2004) have measured group cohesion with the support of survey information. However, log data to measure changes of group cohesion within a group were not used. This issue may be due to limited approaches to accurately analyse group cohesion based on behavioural and cognitive indicators over time. This circumstance can be attributed to the lack of approaches to measure group cohesion from temporal data. Another reason for researchers not utilising the data may be attributed to ethical limitations that prevent the use of log data or certain study constraints where that data is not needed. Overall, the studies considered in the review suggest that there is a missed opportunity to understand further how group cohesion processes in technology-mediated environments evolve using well established analytical techniques. Future research in this context needs to consider examining group cohesion development and utilise temporal methodologies to understand the emergence of the group cohesion to understand the implications it has for the students' overall collaborative learning.

6.2. Log (Trace) Data

A prominent observation made in this review was the lack of log data to support the analysis of group cohesion in technology-mediated learning contexts. Findings show a limited number of studies ($n = 5$) out of 30 that strictly harness log data to measure group cohesion from engagement data (Altebarmakian & Alterman, 2019a; Heo et al., 2010; Reffay et al., 2011; Reffay & Chanier, 2003; Y. Wang & Li, 2008). Researchers tend to rely on surveys to measure specific dimensions of group cohesion such as task, social, belongingness, morale, group pride, and others. However, more can be done to enrich our understanding of group cohesion by using log data. In LA and EDM, log data collected from the traces of learner activity within a learning management platform has been used to understand the processes of learning (Wise, 2019). Research methodologies in this field often entail a mixture of qualitative and quantitative approaches to understand the way students learn and behave in technology-mediated learning environments. For instance, the collected data is often used to measure individuals' cognitive and regulated learning abilities or the collaboration of groups to establish a connection with their learning outcomes (Baker & Inventado, 2014; Winne, 2017). Similar approaches can be used to connect group cohesion development and the relationship with learning and performance. The benefits of doing such work will allow educators to support group members where cohesion is minimal.

Log data has the potential to yield important discoveries of group cohesion processes where it would not have been possible using survey information. Furthermore, the use of log data would allow for interesting insights when coupled with data mining techniques to increase our knowledge of the dynamics of group cohesion and how it connects with the learner's behaviours. The use of strictly embracing log data is not to say that measuring group cohesion with surveys or self-reports should phase out. On the contrary, surveys will have a crucial role in validating the novel and methodological approaches to establish generalisability progressively with log data.

6.3. Implications for Design and Research Practice

For the past two decades, most researchers who engaged in studying group cohesion within a technology-mediated collaborative learning environment have measured and analysed cohesion

as a static, rather than a dynamic construct due to the extensive cross-sectional research. Given that cohesion is an emergent state that changes over time in groups, there are currently insufficient answers and a gap in this area to address how it impacts individual members and their learning and performance progression. As such, it creates a problem for instructors, as they have no tools available to identify, monitor, and provide pedagogical support for groups when cohesion levels lower, putting members at risk. The problem is further exasperated with the increasing challenges of online learning, where many teams learn autonomously at a distance with less support than traditional environments (Anshari et al., 2016; Wallace, 2003). Providing obtrusive surveys in such environments at regular intervals to potentially large numbers of teams is highly inefficient and a time-consuming process (Visser et al., 2000). The expectation that group members will be motivated enough to complete them and accurately is not realistic.

A prominent strand of innovation relates to producing novel assessment practices by utilising computational approaches in addition to instrument driven ones (Hu et al., 2017). This is an important shift that mirrors trends in computational social sciences (Lazer et al., 2009), where data is used to model and evaluate human behaviour, expanding the range of measures beyond established assessment instruments such as surveys. The computational psychometrics approach blends psychometrics and learning analytics resulting in multimodal data which provide granular construct evidence that would not be achievable using only one of the aforementioned approaches. This blend of psychometrics and learning analytics, besides utilising various data sources (e.g., log data, assessments, and survey data as well as from aggregated information), is specifically suited for near real-time assessment of learning processes and formative feedback purposes that will help measure and assess cohesion in collaborative groups.

Another promising approach to addressing the emerging issues in this review, such as collecting relevant data, monitoring the emergence of cohesion and providing the tailored pedagogical support for collaborative learning groups, is to incorporate artificial intelligence (AI) that harnesses data from an LMS based on learner member interactions (S. J. H. Yang et al., 2021). Increasingly, AI is becoming used more frequently in pedagogy to provide intelligent support for collaborative learning. For instance, AI can help with: 1) automated group formation by placing individual members with complementary skills and knowledge; 2) expert facilitation to provide collaborative learning groups with effective problem-solving strategies; 3) intelligent virtual agents that mediate student interactions and; 4) intelligence moderation where the AI

agent can help augment and support the collaborative learning of groups through dashboards or informing human tutors to promote cohesion and learning (Luckin et al., 2016). Several case studies found in this review promote the notion of enabling AI agents to support collaborative learning and improving the cohesion of groups (Terzidou et al., 2016; F. G. Yilmaz & Yilmaz, 2019). It is recommended that researchers create environments to support AI systems and foster collaborative learning and cohesion over time. Although, such endeavours are complex and require extensive research and resources to undertake. For example, designing technological infrastructure and gathering the 'right' data for the given context to undertake AI in education (Luckin et al., 2016). Therefore, advancing psychometrics in conjunction with learning analytics to collect relevant data that can be referenced is paramount to promote AI research and provide augmented support

Given that the existing studies and design implementations to help facilitate group cohesion in technology-mediated learning contexts are very limited, additional research is required to help advance this area. Researchers in education and teaching must not restrict themselves to in-house literature but explore and take inspiration from other disciplines that had extensively studied team dynamics to facilitate learning, cohesion, and performance experiences. In organisational sciences, researchers have extensively studied the area of team cognition and learning (Mohammed et al., 2021). There is great potential to utilise ideas across disciplines for an educational context that is highly innovative to advance collaborative learning and cohesion studies in the educational sphere. Based on this review and the gaps identified, researchers are encouraged to enable technologies that help capture, measure, and analyse the temporal development of group cohesion in technology-mediated learning environments. Such approaches will help increase the understanding of the dynamic relationships between cohesion, collaborative learning, and performance and help instructors augment and support the learning of collaborative groups.

7. Conclusions

The definition and measurement of cohesion within small groups participating in learning experiences have been frequently studied. However, the research in technology-mediated learning commonly defining group cohesion, including the methodological approaches to measure and analyse it and the factors that facilitate and impact group cohesion in small groups,

was unknown. This literature review contributes to the number of gaps identified within the review with recommendations for future work. Firstly, studies researching group cohesion and how it emerges in CSCL literature contexts using temporal techniques remain scarce. The findings that substantiate and influence cohesion in technology-mediated settings have been outlined and conceptualised using Salas et al. (2015) categories of cohesion (i.e. task, social, belongingness, morale and group pride). The review identified that only task cohesion, belongingness and group pride impacts the performance outcomes of collaborative learning groups. Only a few studies in this review have utilised design-based research methodologies to facilitate group cohesion. As a result, further studies are required to conduct design-based research and continually improve the learning environment of collaborative groups and identify what interventions enhance the cohesion of groups, given the challenges of online learning environments (Anshari et al., 2016). Furthermore, there is a gap in providing instructors with the tools to support the development of cohesion in groups over time in these environments and it remains to be addressed. Overall, the argument of this review points to the limited studies that had taken steps to appropriately validate or test claims of a design improving the cohesion of collaborative learning groups. The review argues the need for research in temporal and analytical-based measures that utilises log data, such as learning trace data collected by various learning environments, to understand how group cohesion evolves over time. In that way, instructors have the means to provide practical support grounded in evidence to help maintain group cohesion in an ever changing environment related to the challenges of the 21st century.

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Appendix A. Overview of the Studies Included in the Systematic Review

Table A.1. Publication Timeline and Study Summary

No.	Ref.	Paper Type	Courses	Group Size	Student Pop	Study Duration	Study Type
1	Altebarmakian and Alterman (2019a)	Journal	Psychology	3-4	29	Single Semester	Design Based-Research
2	Altebarmakian and Alterman (2019b)	Conference	Computer	3-5	95	Single Semester	Design Based-Research
3	Beranek and Martz (2005)	Journal	Science	3	59	8 weeks	Cross Sectional
4	Bilgin and Gul (2020)	Journal	Computer	3-4	92	13 weeks	Cross Sectional
5	Castro-Hernandez et al. (2015)	Conference	Science	5	73	Single Semester	Cross Sectional
6	Castro-Hernandez et al. (2016)	Conference	Technology	4-5	178	Single Semester	Cross Sectional
7	David et al. (2006)	Conference	Computer	5	110	Single Semester	Cross Sectional
8	Galyon et al. (2016)	Journal	Science	3-5	68	Two Semesters	Cross Sectional
9	Garcia & Privado (2020)	Journal	Computer	4-5	139	8 weeks	Cross Sectional
10	Gonzales et al. (2010)	Journal	Science	4-5	233	3 months	Longitudinal
11	Guo et al. (2010)	Journal	Computer	4-6	324	NA	Cross Sectional
12	Hansen (2016)	Journal	Science	4	50	2 years	Cross Sectional
13	Heo et al. (2010)	Journal	Psychology	7	49	16 weeks	Cross Sectional
14	Lam (2015)	Journal	Education	3-5	445	NA	Cross Sectional
15	Lu and Xie (2018)	Journal	Technology	4-5	171	7 weeks	Cross Sectional
16	Reffay and Chanier (2003)	Journal	Technology	4	40	10 weeks	Cross Sectional
17	Reffay et al. (2011)	Conference	Marketing	4	40	10 weeks	Cross Sectional
18	Rogers and Lea (2004)	Conference	Technology	3-4	35	4 weeks	Longitudinal
19	Shin and Song (2011)	Conference	Technology	3-4	301	Two Semesters	Cross Sectional
20	Tseng and Yeh (2013)	Journal	Education	4	15	15 weeks	Cross Sectional
21	Terzidou et al. (2016)	Conference	Technology	2-3	41	1 week	Cross Sectional
22	Wang and Li (2008)	Journal	Language	4-5	29	Single Semester	Cross Sectional
23	Wang and Hwang (2012)	Journal	Language	3	75	Single Semester	Cross Sectional
24	Wang and Hong (2018)	Conference	Education	3	96	4 weeks	Cross Sectional
25	Williams et al. (2006)	Journal	Human	2-10	300	12 weeks	Cross Sectional
26	Xie et al. (2019)	Journal	Mathematics	5-7	171	Single Semester	Cross Sectional
27	Yilmaz and Yilmaz (2019)	Journal	Technology	3-	50	10 weeks	Cross Sectional
28	Yilmaz et al. (2020)	Journal	Computer	3-5	41	12 weeks	Cross Sectional
29	Zheng (2017)	Journal	Science	3-4	90	8 weeks	Cross Sectional
30	Zheng et al. (2014)	Conference	Technology	4	126	Single Semester	Cross Sectional

Table A.2. Definitions, Measures and Analysis

No.	Ref.	Multi-dimensions	Dimensions	Focus of Measurement	Level of Measurement	Level of Analysis
1	Altebarmakian and Alterman (2019a)	Multidimension	Task/Social Cohesion	Mixed	Mixed	Mixed
2	Altebarmakian and Alterman (2019b)	Multidimension	Task/Social Cohesion	Mixed	Mixed	Mixed
3	Beranek and Martz (2005)	Unidimension	Morale	Attitude	Group Level	Group Level
4	Bilgin and Gul (2020)	Multidimension	Belongingness	Mixed	Group Level	Group Level
5	Castro-Hernandez et al. (2015)	Unidimension	Task Cohesion	Behaviour	Mixed	Mixed
6	Castro-Hernandez et al. (2016)	Unidimension	Task Cohesion	Mixed	Mixed	Mixed
7	David et al. (2006)	Unidimension	Morale/Belongingness	Behaviour	Individual Level	Group Level
8	Galyon et al. (2016)	Multidimension	Belongingness	Attitude	Individual Level	Group Level
9	Garcia & Privado (2020)	N/A	Task Cohesion	Mixed	Individual Level	Individual Level
10	Gonzales et al. (2010)	Multidimension	Group Pride	Behaviour	Mixed	Group Level
11	Guo et al. (2010)	Unidimension	Belongingness	Attitude	Mixed	Group Level
12	Hansen (2016)	Multidimension	Belongingness	Mixed	Mixed	Group Level
13	Heo et al. (2010)	N/A	N/A	N/A	Mixed	Mixed
14	Lam (2015)	Multidimension	Task Cohesion	Mixed	Mixed	Individual Level
15	Lu and Xie (2018)	Multidimension	Belongingness	Attitude	Individual Level	Group Level
16	Reffay and Chanier (2003)	N/A	N/A	N/A	Mixed	Mixed
17	Reffay et al. (2011)	N/A	N/A	N/A	Mixed	Mixed
18	Rogers and Lea (2004)	Multidimension	Belongingness	Mixed	Mixed	Mixed
19	Shin and Song (2011)	Multidimension	Task/Social Cohesion	Mixed	Mixed	Mixed
20	Tseng and Yeh (2013)	Unidimension	Belongingness	Attitude	Group Level	Group Level
21	Terzidou et al. (2016)	N/A	N/A	N/A	Group Level	Group Level
22	Wang and Li (2008)	N/A	N/A	Mixed	Group Level	Group Level
23	Wang and Hwang (2012)	Multidimension	Task Cohesion	Behaviour	Mixed	Mixed
24	Wang and Hong (2018)	Unidimension	Task/Social Cohesion	Mixed	Mixed	Mixed
25	Williams et al. (2006)	Multidimension	Belongingness	Behaviour	Individual Level	Group Level
26	Xie et al. (2019)	Multidimension	Morale/Belongingness	Attitude	Individual Level	Group Level
27	Yilmaz and Yilmaz (2019)	Multidimension	Belongingness	Mixed	Individual Level	Individual Level
28	Yilmaz et al. (2020)	Multidimension	Belongingness	Behaviour	Mixed	Group Level
29	Zheng (2017)	Multidimension	Task/Social Cohesion	Attitude	Mixed	Group Level
30	Zheng et al. (2014)	Multidimension	Task/Social Cohesion	Mixed	Mixed	Group Level

Table A.3. Environment, Technology and Design

No.	Ref.	Learning Environment	Learning Technology	Design Orientated	Design Detail
1	Altebarmakian and Alterman (2019a)	Blended Learning	Learning Management System	Yes	Homework platform
2	Altebarmakian and Alterman (2019b)	Blended Learning	Learning Management System	Yes	Homework platform
3	Beranek and Martz (2005)	Online Learning	Learning Management System	Yes	Relationship link training
4	Bilgin and Gul (2020)	Blended Learning	Learning Management System	Yes	Exposure to gaming elements
5	Castro-Hernandez et al. (2015)	Online Learning	Learning Management System	Yes	Cohesion-related feedback system
6	Castro-Hernandez et al. (2016)	Online Learning	Learning Management System	No	N/A
7	David et al. (2006)	Blended Learning	Learning Management System	No	N/A
8	Galyon et al. (2016)	Blended Learning	Learning Management System	No	N/A
9	Garcia & Privado (2020)	Online Learning	Learning Management System	No	N/A
10	Gonzales et al. (2010)	Blended Learning	Learning Management System	No	N/A
11	Guo et al. (2010)	Blended Learning	Media Communication	No	N/A
12	Hansen (2016)	Blended Learning	Learning Management System	No	N/A
13	Heo et al. (2010)	Blended Learning	Learning Management System	No	N/A
14	Lam (2015)	Blended Learning	Learning Management System	No	N/A
15	Lu and Xie (2018)	Online Learning	Learning Management System	No	N/A
16	Reffay and Chanier (2003)	Online Learning	Learning Management System	No	N/A
17	Reffay et al. (2011)	Online Learning	Learning Management System	No	N/A
18	Rogers and Lea (2004)	Online Learning	Media Communication	Yes	Shared social identity
19	Shin and Song (2011)	Blended Learning	Media Communication	No	N/A
20	Tseng and Yeh (2013)	Online Learning	Learning Management System	No	N/A
21	Terzidou et al. (2016)	Blended Learning	Agent Based	Yes	Pedagogical agent to support learning
22	Wang and Li (2008)	Online Learning	Learning Management System	No	N/A
23	Wang and Hwang (2012)	Online Learning	Learning Management System	No	N/A
24	Wang and Hong (2018)	Online Learning	Learning Management System	No	N/A
25	Williams et al. (2006)	Online Learning	Learning Management System	No	N/A
26	Xie et al. (2019)	Online Learning	Learning Management System	No	N/A
27	Yilmaz and Yilmaz (2019)	Blended Learning	Agent Based	Yes	Group awrareness tool using pedagogical agent
28	Yilmaz et al. (2020)	Online Learning	Learning Management System	No	N/A
29	Zheng (2017)	Online Learning	Media Communication	Yes	Socially shared regulated learning mechanism
30	Zheng et al. (2014)	Online Learning	Learning Management System	No	N/A

Table A.4. Methodology, Statistical Approaches and Factor Groups

No.	Ref.	Method Conduct	Method Type	Data Format	Factor Group	Factors	Performance
1	Altebarmakian and Alterman (2019a)	Unobtrusive	Quantitative	Log data	Substantiating	Engagement	Yes
2	Altebarmakian and Alterman (2019b)	Mixed	N/A	N/A	Other	N/A	N/A
3	Beranek and Martz (2005)	Obtrusive	Quantitative	Survey	Other	Relational link Training	No
4	Bilgin and Gul (2020)	Obtrusive	Quantitative	Survey	Substantiating	Gaming	Yes
5	Castro-Hernandez et al. (2015)	Mixed	Mixed	Mixed	Substantiating	Cohesion-based feedback	No
6	Castro-Hernandez et al. (2016)	Mixed	Mixed	Mixed	Substantiating	Linguistic style matching	Yes
7	David et al. (2006)	Obtrusive	Quantitative	Survey	Other	N/A	N/A
8	Galyon et al. (2016)	Obtrusive	Quantitative	Survey	Substantiating	Participation	No
9	Garcia & Privado (2020)	Obtrusive	Quantitative	Survey	Influencing	Satisfaction	N/A
10	Gonzales et al. (2010)	Mixed	Mixed	Mixed	Substantiating	Linguistic style matching	Yes
11	Guo et al. (2010)	Obtrusive	Quantitative	Survey	Substantiating	Group similarity	No
12	Hansen (2016)	Obtrusive	Quantitative	Survey	Influencing	Communication	N/A
13	Heo et al. (2010)	Unobtrusive	Quantitative	Log data	Substantiating	Networks	No
14	Lam (2015)	Obtrusive	Quantitative	Survey	Substantiating	Communication quality	No
15	Lu and Xie (2018)	Obtrusive	Quantitative	Survey	Substantiating	Mastery goals	No
16	Reffay and Chanier (2003)	Unobtrusive	Quantitative	Log data	Substantiating	Networks	No
17	Reffay et al. (2011)	Unobtrusive	Quantitative	Log data	Substantiating	Networks	No
18	Rogers and Lea (2004)	Obtrusive	Quantitative	Survey	Substantiating	Shared identity	No
19	Shin and Song (2011)	Obtrusive	Quantitative	Survey	Other	N/A	N/A
20	Tseng and Yeh (2013)	Obtrusive	Qualitative	Survey	Influencing	Trust	N/A
21	Terzidou et al. (2016)	Obtrusive	Quantitative	Survey	Substantiating	Gaming	Yes
22	Wang and Li (2008)	Unobtrusive	Quantitative	Log data	Substantiating	Networks	No
23	Wang and Hwang (2012)	Obtrusive	Quantitative	Survey	Substantiating	Collective efficacy	Yes
24	Wang and Hong (2018)	Obtrusive	Quantitative	Survey	Substantiating	Collective task value	Yes
25	Williams et al. (2006)	Obtrusive	Quantitative	Survey	Substantiating	Teamwork orientation	Yes
26	Xie et al. (2019)	Mixed	Quantitative	Mixed	Influencing	Engagement	Yes
27	Yilmaz and Yilmaz (2019)	Obtrusive	Quantitative	Survey	Substantiating	Metacognitive support	No
28	Yilmaz et al. (2020)	Obtrusive	Quantitative	Survey	Influencing	Leadership	N/A
29	Zheng (2017)	Obtrusive	Quantitative	Survey	Substantiating	SSRL	Yes
30	Zheng et al. (2014)	Obtrusive	Quantitative	Survey	Substantiating	Roles	No

Table A.5. Methodology, Statistical Approaches and Factor Groups

Statistical Approach	Authors	No.
Regression	(Garcia & Privado 2020; Gonzales et al. 2010; Lu & Xie 2018; Rogers & Lea 2004; Wang & Hong 2018; Williams et al. 2006; Zheng 2017)	9,10,15 18,24,25,29
Social Network Analysis	(Heo et al. 2010; Reffay & Chanier 2003; Reffay et al. 2011; Wang & Li 2008)	13,16,17,22
Factor Analysis	(David et al. 2006; Shin & Song 2011; Wang & Hwang 2012; Wang & Hong 2018)	7,19,23,24
T-test	(Bilgin & Gul 2020; Terzidou et al. 2016; Yilmaz & Yilmaz 2019; Yilmaz et al. 2020; Zheng 2017)	4,21,28,30
Linguistic Style Matching	(Castro-Hernandez et al. 2015, 2016; Gonzales et al. 2010)	5,6,10
ANOVA	(Hansen 2016; Williams et al. 2006; Zheng et al. 2014)	12,25,29
ANCOVA	(Bilgin & Gul 2020; Terzidou et al. 2016; Yilmaz & Yilmaz 2019; Yilmaz et al. 2020)	4,21,27,28
MANOVA	(Beranek & Martz 2005; Galyon et al. 2016)	3,8
Partial Least Squares Analysis	(Guo et al. 2019; Lam 2015)	11,14
Levene's Test	Castro-Hernandez et al. (2015)	5
Partial Correlation Test	Castro-Hernandez et al. (2016)	6
Structural Equation Modelling	Xie et al. (2019)	25
Information Exchange Similarity, Rate	Castro-Hernandez et al. (2016)	6
Thematic Analysis	Tseng & Yeh (2013)	20

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