

ORIGINAL ARTICLE

Open Access



Remote collaborative process optimization in research and design of industrial manufacturing

Siqin Wang^{1*} and Qingdu Li²

Abstract

In response to the impact of COVID-19, the manufacturing industry and academic industrial research have largely shifted to online or hybrid conference formats. The sudden change has posed challenges for researchers and teams to adapt. Based on the current state of online conferences, inadequate communication, disruptions during meetings, confusion and loss of meeting information, and difficulties in conducting online collaborations are observed. This paper presents a design of a real-time discussion board that combines online conferences and synchronous discussions to address the issues arising from remote collaborations in industrial research. The research demonstrates that synchronous discussions conducted within multi-team industrial collaboration teams with specific and diverse issues can better control the flow of meetings, enhance meeting efficiency, promote participant interaction and engagement, reduce information loss, and weaken the boundaries between online and offline collaboration.

Keywords: Human-computer interaction, User experience design, Human-computer collaboration, User interface design

1 Introduction

In the context of the ongoing digital transformation of work and research, it is necessary to improve existing traditional processes and collaboration models to enhance research efficiency and promote teamwork in academic research domains [1]. Contemporary industrial research often relies on multidisciplinary collaboration [2]. With the continuous advancement of information technology and the impact of COVID-19, online collaboration modes are gradually being popularized across various fields. To meet the evolving demands of remote work, this study proposes an optimized design for online meeting information and processes, aiming to address the challenges encountered in remote collaboration among multiple teams within the industrial framework. Research indicates that large-scale virtual writing and innovation are complementary, and im-

proved information technology can enhance virtual collaboration among teams and potentially enhance innovation capabilities [3]. Although maintaining persistent attention and facilitating meaningful interaction among participants in an online environment remains challenging [4, 5], online meeting software continues to be the primary means of remote collaboration in academic industrial research. Furthermore, the blurring of boundaries between online interaction and offline collaboration in online collaboration is a positive development for research and development processes that heavily rely on interactive communication [6].

Effective communication and interaction during online meetings play a crucial role in enhancing meeting effectiveness [7]. The absence of body language and eye contact in online meetings can lead to feelings of isolation among participants, thereby reducing their willingness to speak up and engage in interaction [8–10]. The voice communication in online meetings does not support multi-person discussions, and live chat can address this limitation. How-

*Correspondence: 983028860@qq.com

¹The University of Queensland, Brisbane, 4072, Australia

Full list of author information is available at the end of the article

ever, participants do not always find live chat conversations consistently effective [11]. Interaction in online meetings encompasses three aspects: interaction among participants, interaction between participants and presenters, and interaction between participants and meeting content [12]. However, as the number of participants increases, the information conveyed through real-time chat may become complex, making it difficult to extract relevant information. Compared to face-to-face meetings, participants in online meetings may engage in a significant amount of meaningless interaction and become distracted due to psychological and technical factors [13, 14]. Furthermore, participants in online meetings often require more effort, which can lead to listener fatigue [15, 16]. Despite the inherent challenges of online meetings, higher education and research increasingly rely on this mode of communication, and participants demonstrate a greater willingness to use real-time chat technology [17, 18]. Online discussion boards are another important communication channel for online audiences. In online learning and collaboration, discussion boards are considered tools that facilitate content understanding and stimulate participant discussions and critical thinking. However, to achieve the intended purposes of supporting learning goals, discussion boards need a clear structure and purpose [19]. Due to prolonged waiting times, many attendees are reluctant to ask questions and participate in discussions on asynchronous discussion boards [20].

As stated above, this paper will primarily focus on optimizing and designing communication and interaction processes in online meetings and collaboration. It is evident that traditional face-to-face education/collaboration and asynchronous discussion approaches are not suitable for online teaching and research [21]. Asynchronous discus-

sions have longer response cycles and are more suitable for researchers to address complex and specific issues [22]. By combining synchronous and asynchronous discussions, effective interaction can be fostered among participants, and a multi-threaded discussion approach can engage the audience in discussions on different domains and topics, thereby preventing information overload within real-time chat boxes [23]. Moreover, when learners engage in too many online tasks synchronously during online meetings, it can have a negative impact on their mental well-being [24]. Clearly, a one-size-fits-all approach to design real-time discussion boards by simply considering synchronous and asynchronous interaction modes is not advisable.

After reviewing the advantages and disadvantages of current online meetings and collaboration, the structure of this paper is as follows: Section 2 elaborates on the main methods used in the research, including state machine diagrams of the interaction process, interview methods, design processes, and approaches. Section 3 expands on the corresponding discussions based on a human-centered design approach and presents the final design prototype. Section 4 discusses the main findings of the research. The last section provides a summary of the conclusions.

2 Methodology

2.1 Visualization of interactive processes

To facilitate the effective design of a real-time discussion board, it is crucial to conduct focus group discussions. Additionally, analyzing the discussion and collaboration process within online meetings and visually representing it through a state machine diagram can provide a more intuitive understanding. Figure 1 illustrates the decision-making process when determining whether to initiate an

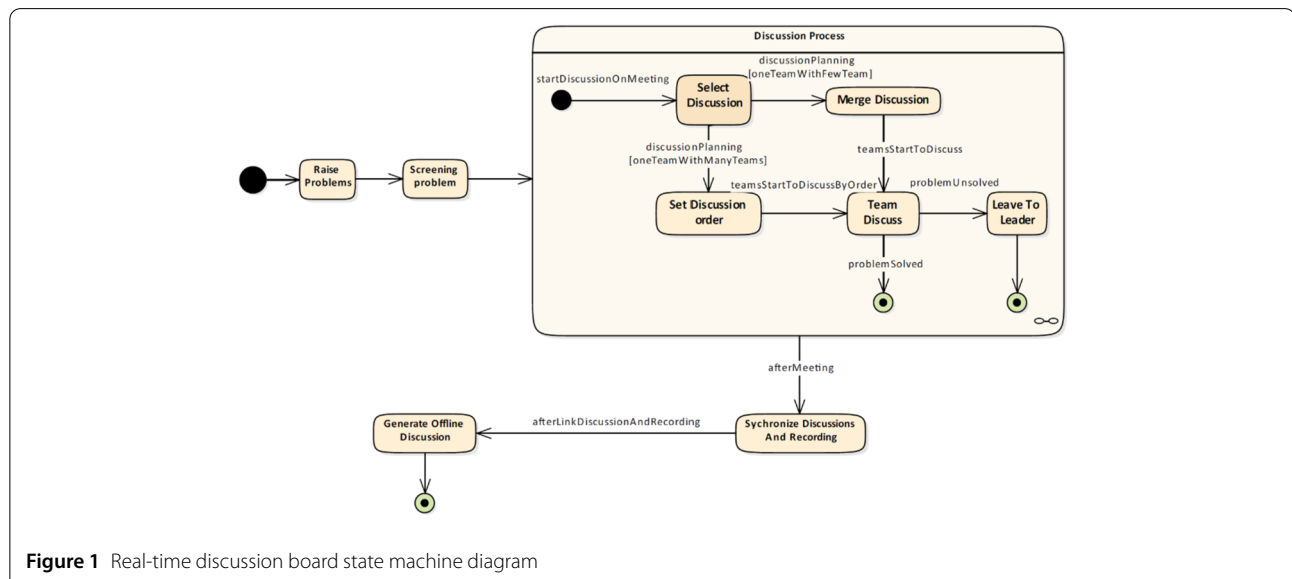


Figure 1 Real-time discussion board state machine diagram

online discussion in response to a question raised during each online meeting. Once the current issues have been identified, if a collaborative problem involves multiple teams, the discussion method needs to be determined based on the number of relevant groups involved. Following the online collaborative discussion, if the problem remains unresolved, it should be escalated to the leader for resolution. Finally, after the meeting concludes, the discussion content and meeting recording should be synchronized and uploaded to the asynchronous discussion board to maintain a record of the problem and enable ongoing discussions.

2.2 Interviews and questionnaires

At the outset of the study, a simple questionnaire survey was conducted to gain a broader understanding of online participants' attitudes towards communication behavior and the usage of discussion boards in online meetings. Recognizing that the presence of teachers and team leaders in focus group meetings may inhibit students and members from expressing their true opinions, a separate online interview method was employed for the hosts of the online meetings.

In order to ensure the collection of real feedback and needs from all target users, this study conducted individual interviews with industrial R&D team leaders and relevant course instructors, which is to understand project leaders' needs and existing flaws in online team collaboration platforms. The two interviewees are an instructor who often organizes students to conduct teamwork in industry-related online courses and a project team leader in an industrial laboratory. The respective areas of expertise are industrial design and software development.

Upon comparing the responses of the two interviewees, it was found that both acknowledged initially paying excessive attention to the online platform, resulting in more time spent than anticipated. They also expressed dissatisfaction with the lack of intuitiveness in the information presentation method of live chat. Nevertheless, the interviewees maintained an optimistic outlook on live chat and proposed new designs for the online meeting process by integrating the existing discussion platform with online meetings. Neither interviewee had the habit of reviewing the live chat once the meetings concluded. Furthermore, based on the interviewees' responses, it was observed that despite the designed online meeting process, more than half of the meetings did not adhere to the specified process. It is apparent that both audiences and leaders exhibit their unique communication and questioning styles during online meetings or collaborations. Designing a more stable online conference interaction method is an inevitable trend in the realm of online meetings and collaborations.

2.3 Workflow setting

During the initial focus group meeting, participants will engage in a comprehensive review and in-depth discussion of the procedures and potential scenarios associated with their inaugural utilization of online meetings and an online discussion board. A qualitative analysis will be conducted, followed by a thorough examination of the validity and limitations of the pertinent scenarios. Subsequently, the group will proceed to formulate the prototype design.

Subsequently, in the second focus group meeting, the design's concept and primary functionalities will be presented to the participants in a comprehensive manner, aiming to demonstrate the design prototype as thoroughly as possible. Feedback will be sought from the second focus group, specifically concerning the real-time discussion boards, and recorded for future reference. This feedback will serve as a foundation for finalizing the design of the real-time discussion board prototype, as a substantial portion of the design concepts and inspirations have been derived from the focus group's feedback on their experiences with relevant courses and manufacturing processes.

2.4 Design and analysis

The primary objective of this article is to enhance the quality of discussions among participants and between different teams in online meetings, while also improving information visualization. Simultaneously, the research aims to provide practical process recommendations for teaching and manufacturing research teams utilizing the real-time discussion board in online meetings. To achieve this, qualitative analysis of the real-time discussion board is conducted by synthesizing the content of the initial group meeting, conducting interviews with teachers and leaders, addressing questions that arise during the design process, and incorporating insights from online discussion boards in relevant courses. The central purpose of this analysis and discussion is to identify and summarize the key accomplishments of the real-time discussion board in practical applications, as well as the potential advantages that the new design may bring to online meetings, employing qualitative research methods.

3 Design and evaluation

3.1 Focus group meetings

First, in order to make the focus group discussion more general and be able to deal with special situations, the group members were selected from those who participated in relevant R&D courses and research groups. Two of the participants were from the same lab, while the other two collaborated, usually online. Additionally, one of the participants was in a different time zone than the other three. Therefore, in order to ensure that the real-time discussion board can be used in both synchronous and asynchronous ways, focus group members choose to make as

diverse choices as possible. At the same time, in order to avoid embarrassing discussions, the focus group avoided the leader of each group.

During the initial focus group meeting, participants unanimously acknowledged the effectiveness of the online discussion board and collaboration platform, specifically the Miro board, in promoting collaboration and interactivity. However, disagreements arose when it came to conducting synchronous discussions simultaneously with online meetings. Two participants expressed difficulties in swiftly transitioning between different software platforms for communication and interaction, particularly on mobile devices. Conversely, two other participants found that the real-time discussion board stimulated their desire to learn and communicate. One participant, due to jet lag and asynchronous work schedules, was unable to actively participate in synchronous discussions. Moreover, all participants agreed that using voice communication for discussions during online meetings proved challenging. Nevertheless, all four participants acknowledged the benefits of synchronous discussions in the context of online meetings. Those who utilized multiple software platforms to achieve synchronous discussions felt that incorporating additional software increased their cognitive load.

Based on the initial focus group meeting, it is recommended to design the real-time discussion board to support both synchronous and asynchronous communication modes, catering to different online participants and enhancing interaction. To address the cognitive load associated with using multiple software platforms, integrating the discussion board within existing online meeting systems, such as a live-chat area, is suggested. This integration would streamline the user experience and promote seamless interaction.

The purpose of the second focus group meeting was to discuss and evaluate the rationale behind the design

concept, aiming to identify potential shortcomings. One participant questioned the effectiveness of combining synchronized discussion content with video footage and expressed concerns about retrieving relevant discussion video recordings. However, overall consensus among the group favored integrating real-time discussion boards into online meeting software to improve efficiency and simplify information sharing. This indicates significant potential for optimizing the online meeting experience through embedded discussion boards.

3.2 Design prototype

The design prototype aims to integrate the discussion board into online meeting software, taking the Zoom meetings as example. Based on the feedback from online group members, this integration is expected to significantly reduce the participants' workload during online meetings.

Figure 2 showcases the final design scheme, incorporating real synchronous discussions and collaborations. Unlike the original approach of using separate discussion software within an online meeting, the real-time discussion board offers three key differences. Firstly, since the discussion board is embedded within the meeting software, the send button allows participants to share regular live-chat information, while the generate discussion button creates a discussion/question area within the real-time discussion board. Selected questions posted to the discussion board can be further deliberated upon by all members or teams, leading to the decision of whether to establish a new online group for discussion. If the issue is resolved, the discussion can continue asynchronously. However, if any unresolved issues persist, the involvement of a leader or teacher will be necessary. The system also records the specific time when relevant problems are resolved, and after the meeting, the jump button allows participants to easily navigate to the

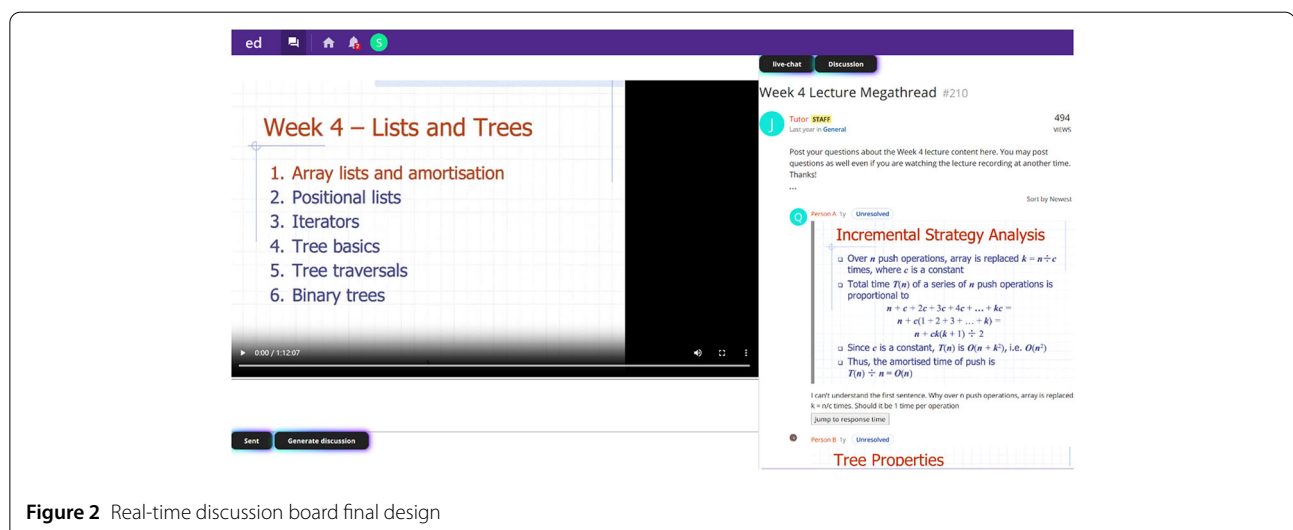


Figure 2 Real-time discussion board final design

corresponding discussion recording area. Unlike information exchanged through regular live-chat boxes, the embedded discussion board system within the conferencing software also enables the preservation of these questions and discussions for subsequent asynchronous collaboration and discussion after the online meeting.

3.3 Design & qualitative analysis

With the gradual easing of travel restrictions, many online meetings are transitioning into hybrid meetings, combining both online and offline collaboration. However, for teachers and leaders, hybrid meetings can present challenges in terms of balancing the dynamics between online and offline participants. Conducting mixed sessions with speakers in such meetings can increase cognitive load, and the host may find themselves needing to repeat information multiple times [25]. Against this backdrop, this study undertakes the design of real-time discussion boards to enhance control over the meeting process and improve participants' communication experience during online meetings. Additionally, the study offers valuable recommendations for optimizing the communication process in online meetings, particularly in the context of manufacturing processes and research.

4 Discussion findings

Having completed the final design and considering relevant user feedback, the following four primary advantages of a real-time synchronous discussion board have been identified and are further discussed.

- (1) Leveraging real-time discussion mode can significantly assist meeting organizers in managing the flow of meetings and improving the overall fluency and effectiveness of online meetings. Through synchronous discussions, nearly all online collaborative processes and issues are integrated within the discussion board. This centralized platform enables efficient problem-solving and collaboration among teams involved in industrial processes, thereby enhancing their ability to address related issues and expediting research progress.
- (2) For participants, engaging in in-depth discussions on complex problems, particularly within industrial manufacturing conglomerates with different tasks, can be challenging to maintain effectively through real-time chats alone. In such cases, employing a discussion board that implements multi-threading and multi-level information representation methods is advantageous. This approach allows the separation of relevant discussion domains based on different issues, enabling participants to engage in detailed discussions through a multi-level conversational mode.

- (3) The use of a discussion board helps alleviate the issue of overlooked information by presenting information in a more prominent and intuitive manner to all participants through a multi-level, multi-threaded data structure.
- (4) The design of the discussion board incorporates both synchronous and asynchronous discussions, thereby retaining the benefits of both modes. This approach ensures that the content of discussions and the collaborative process can continue to engage participants even after the meeting. As a result, it significantly reduces the perceived boundaries between online collaboration and offline work. This overall collaborative approach represents a positive and robust development in the manufacturing industry and industrial research field, as it promotes smoother and more effective exchange of thoughts and knowledge across various backgrounds.

The present study primarily focuses on exploring the crucial role of synchronous discussions in online meetings and collaborations. Furthermore, it is imperative to address the emotional states and individual needs of participants in online meetings and collaborations. Thus, an essential area that requires attention is the incorporation of a more Human-Centered approach to requirements analysis in future research and design endeavors. The advancement of artificial intelligence provides opportunities to explore the utilization and significance of natural language processing technology in online/hybrid meetings, thereby facilitating convenient research practices and fostering multilingual cooperation. Hence, future considerations should be given to leveraging the evolving capabilities of artificial intelligence and natural language processing technology to enhance the efficiency and effectiveness of online/hybrid meetings, while accommodating the diverse linguistic needs of participants.

5 Conclusion

By addressing the current limitations in communication during online meetings within university industrial research and manufacturing processes, this study identifies the drawbacks of live-chat, including information confusion, difficulty in locating important information, challenges in preserving information, and potential interference for the meeting host. To tackle these shortcomings, the paper proposes the implementation of a discussion board to regulate real-time chat behavior during online meetings. Through the development of this real-time discussion board, the research asserts that by standardizing textual information exchange in online meetings, better control over meeting progression can be achieved, enhancing participant interaction, reducing the risk of information loss, and bridging the gap between online and offline work styles. Furthermore, this paper provides recommendations for the online collaboration team to effectively

manage meetings. Emphasizing the importance of meeting interaction and communication processes, the design of online meetings should prioritize participants' engagement to ensure their interaction needs are met adequately.

6 Further work

Recently, with the emergence of artificial intelligence such as chat-GPT3 and other generative artificial intelligence, more novel forms of online cooperation may be possible. For example, an intelligent assistant can be used for online collaboration and automatic translating during meetings. Therefore, if artificial intelligence assistants of different cooperation systems can be trained in the form of online cooperation, it will have a great improvement and beneficial impact on future remote collaborative operations and meetings. Therefore, future design will focus on the effective combination and application of artificial intelligence and online collaboration.

Acknowledgements

Thanks to all the potential users who participated in the design.

Funding

No funding was received for this study.

Availability of data and materials

The focus group phase data summary is presented in the article. In order to protect the privacy of the participants, the more detailed minutes of the meeting will not be made public. If have any further reasonable requirements can request for the author Siqin Wang.

Code availability

Not applicable.

Declarations

Ethics approval and consent to participate

All the research data were agreed and supported by the participants. All the forum data are from real users and no personal information and characteristics can be identified.

Consent for publication

Not applicable.

Competing interests

The authors declare there are no competing financial and non-financial interests in this study.

Author contributions

The idea was inspired by online collaboration during the pandemic when SW discussed with QL, and conducted research analysis, design prototypes and group meetings. The data collection work was completed by SW under the guidance of QL. All authors read and approved the final manuscript.

Authors' information

Siqin Wang: School of Information Technology and Electrical Engineering, The University of Queensland, Brisbane, 4072, Australia. Qingdu Li: Institute of Machine Intelligence, University of Shanghai for Science and Technology, Shanghai, 200093, China.

Author details

¹The University of Queensland, Brisbane, 4072, Australia. ²University of Shanghai for Science and Technology, Shanghai, 200093, China.

Received: 26 July 2023 Revised: 11 October 2023

Accepted: 1 November 2023 Published online: 20 November 2023

References

1. L.M. Castro Benavides, J.A. Tamayo Arias, M.D. Arango Serna, J.W. Branch Bedoya, D. Burgos, Digital transformation in higher education institutions: a systematic literature review. *Sensors* **20**(11), 3291 (2020). <https://doi.org/10.3390/s20113291>
2. L. Leydesdorff, I. Ivanova, The measurement of 'interdisciplinarity' and 'synergy' in scientific and extra-scientific collaborations. *J. Assoc. Inf. Sci. Technol.* **72**(4), 387–402 (2021). <https://doi.org/10.1002/asi.24416>
3. M. Zamiri, L.M. Camarinha-Matos, Organizational structure for mass collaboration and learning, in *IFIP Advances in Information and Communication Technology* (Springer, New York, 2019), pp. 14–23. https://doi.org/10.1007/978-3-030-17771-3_2
4. A.D. Thompson, D. Lindstrom, D.A. Schmidt-Crawford, COVID-19 era: a time for us to lead! *J. Digit. Learn. Teach. Educ.* **36**(4), 204–205 (2020). <https://doi.org/10.1080/21532974.2020.1813238>
5. Y.B. Hermanto, V.A. Srimulyani, The challenges of online learning during the COVID-19 pandemic. *Jurnal Pendidikan dan Pengajaran* **54**(1), 46–57 (2021). <https://doi.org/10.23887/jpp.v54i1>
6. B. Oyarzun, C. Hancock, S. Salas, F. Martin, Synchronous meetings, community of inquiry, COVID-19, and online graduate teacher education. *J. Digit. Learn. Teach. Educ.* **37**(2), 111–127 (2021). <https://doi.org/10.1080/21532974.2021.1890653>
7. J. Wang, Y. Wang, Compare synchronous and asynchronous online instruction for science teacher preparation. *J. Sci. Teacher Educ.* **32**(3), 265–285 (2021). <https://doi.org/10.1080/1046560X.2020.1817652>
8. M.A. Capello, A. Shaughnessy, The why, what, and how of virtual meetings: our toolkit. *Lead. Edge* **39**(8), 598–599 (2020). <https://doi.org/10.1190/tle39080598.1>
9. N. Mu, Using zoom to support English learning during COVID-19 pandemic: strengths and challenges. *J. Ilm. Sek. Dasar* **5**(2), 222–230 (2021)
10. A. Sunarwan, A. Madkur, B.D.A. Putra, An exploration of barriers in learning to speak English in online setting amidst COVID-19 pandemic: a case of sophomore students in an Indonesian Islamic University. *J. Vis. Ilmu Pendidik.* **14**(2), 155 (2022). <https://doi.org/10.26418/jvip.v14i2.52829>
11. G. Oliveira, J. Grenha Teixeira, A. Torres, C. Morais, An exploratory study on the emergency remote education experience of higher education students and teachers during the COVID-19 pandemic. *Br. J. Educ. Technol.* **52**(4), 1357–1376 (2021). <https://doi.org/10.1111/bjet.13112>
12. K.H. Tan, P.P. Chan, N.E. Mohd Said, Higher education students' online instruction perceptions: a quality virtual learning environment. *Sustainability* **13**(19), 10840 (2021). <https://doi.org/10.3390/su131910840>
13. K. Nurhadi, S.N. Putri, A. Wati, Undergraduate students' experiences on online learning due to COVID-19 pandemic: the influence of engagement and pedagogical characteristic in EFL context. *Acad. J. Perspect. Edu. Lang. Lit.* **9**(2), 124 (2022). <https://doi.org/10.33603/perspective.v9i2.6241>
14. R. Meulenbroeks, Suddenly fully online: a case study of a blended university course moving online during the COVID-19 pandemic. *Heliyon* **6**(12), e05728 (2020). <https://doi.org/10.1016/j.heliyon.2020.e05728>
15. K.A. Karl, J.V. Peluchette, N. Aghakhani, Virtual work meetings during the COVID-19 pandemic: the good, bad, and ugly. *Small Group Res.* **53**(3), 343–365 (2022). <https://doi.org/10.1177/10464964211015286>
16. R. Meulenbroeks, W.R. van Joolingen, Students' self-reported well-being under corona measures, lessons for the future. *Heliyon* **8**(1), e08733 (2022). <https://doi.org/10.1016/j.heliyon.2022.e08733>
17. R. Zhang, N.C. Bi, T. Mercado, Do zoom meetings really help? A comparative analysis of synchronous and asynchronous online learning during COVID-19 pandemic. *J. Comput. Assist. Learn.* **39**(1), 210–217 (2023). <https://doi.org/10.1111/jcal.12740>
18. J. Broadbent, J. Lodge, Use of live chat in higher education to support self-regulated help seeking behaviours: a comparison of online and blended learner perspectives. *Int. J. Educ. Technol. Higher Educ.* **18**(1) (2021). <https://doi.org/10.1186/s41239-021-00253-2>
19. S. Fehrman, S.L. Watson, A systematic review of asynchronous online discussions in online higher education. *Am. J. Distance Educ.* **35**(3), 200–213 (2021). <https://doi.org/10.1080/08923647.2020.1858705>
20. V.T. Le, N.H. Nguyen, T.L.N. Tran, L.T. Nguyen, T.A. Nguyen, M.T. Nguyen, The interaction patterns of pandemic-initiated online teaching: how teachers adapted. *System* **105**(2–3), 102755 (2022). <https://doi.org/10.1016/j.system.2022.102755>
21. P.R. Lowenthal, M. Johnson, Strategies to improve the use of live synchronous meetings in blended, remote, and online courses. *NwELearn* **2**(1) (2022). <https://doi.org/10.5399/osu/nwelearn.2.1.5641>

22. K. Rollag, Teaching business cases online through discussion boards: strategies and best practices. *J. Manag. Educ.* **34**(4), 499–526 (2010). <https://doi.org/10.1177/1052562910368940>
23. D.S. Ackerman, B.L. Gross, Synchronous online discussion board as a primary mode of delivering marketing education: responding to the COVID-19 pandemic and beyond. *Mark. Educ. Rev.* **31**(4), 284–293 (2021). <https://doi.org/10.1080/10528008.2021.1893752>
24. N.H. Al-Kumaim, F. Mohammed, N.A. Gazem, Y. Fazea, A.K. Alhazmi, O. Dakkak, Exploring the impact of transformation to fully online learning during COVID-19 on Malaysian University students' academic life and performance. *Int. J. Interac. Mob. Technol.* **15**(5), 140–158 (2021). <https://doi.org/10.3991/ijim.v15i05.20203>
25. R. Ellis, T. Goodacre, N. Mortensen, R.S. Oeppen, P.A. Brennan, Application of human factors at hybrid meetings: facilitating productivity and inclusivity. *Br. J. Oral Maxillofac. Surg.* **60**(6), 740–745 (2022). <https://doi.org/10.1016/j.bjoms.2021.12.055>

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Submit your manuscript to a SpringerOpen[®] journal and benefit from:

- ▶ Convenient online submission
- ▶ Rigorous peer review
- ▶ Open access: articles freely available online
- ▶ High visibility within the field
- ▶ Retaining the copyright to your article

Submit your next manuscript at ▶ [springeropen.com](https://www.springeropen.com)
