Interactions Beyond the Pandemic: Lessons Learned from Large-scale Emergency Remote Teaching in Higher Education

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Abstract

Online education — given the enhanced access for diverse populations and flexible participation — has been a topic of interest for many computer science and learning science researchers. The sudden shift to online settings during the COVID-19 Emergency Remote Teaching (ERT) provided a valuable opportunity to examine the use of educational technologies on a global scale with various digital readiness skills, beyond many past works that relied on small lab studies. Following a PRISMA-inspired methodology grounded on Moore's three types of classroom interaction, this descriptive review investigates 22 empirical research papers published during the COVID-19 ERT era focused on higher-education online classrooms. We explore the empirical evidence reported in the collected corpus, and given how ERT remains a likely future occurrence, we suggest key directions for future research, including a new learning paradigm that centralizes and augments Learner-Content interaction to balance between flexibility and structure of online learning.

CCS Concepts

• **Human-centered computing** → **Human computer interaction (HCI)**.

Keywords

Online Classroom, Higher Education, Learning Interactions, Emergency Remote Education

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1 Introduction

While in-person teaching is the status-quo in higher education, synchronous online environments have the potential to improve scale of learning and provide flexibility for remote learners. Compared to traditional face-to-face education, distance learning is more self-paced [18, 21] in which students can benefit from the enhanced flexibility regarding location, timing, and participation modalities [68, 84, 141]. Distance learning mitigates geographical barriers and further enables more diverse set of students to partake in quality education.

The recent COVID-19 pandemic was a rare event in which online learning prevailed as the sole medium for delivering education on a global scale. Following this pandemic and as part of strict social distancing measures, all forms of in-person education turned into online formats, a circumstance known as *Emergency Remote Teaching* (ERT). According to a US-wide survey in 2020, 84% of the participating undergraduate students indicated taking at least one online class [23]. Educators of this ERT era needed to swiftly modify existing in-person curricula into online formats that might have not always aligned with the elements of a successful online course; during this period many students severely struggled to cope with the mechanisms and technology affordances of online learning [14].

The COVID-19 ERT era offers a unique time in the online education space, given that — unlike many pre-pandemic studies that utilize short-term and controlled lab studies — most students world-wide were affected by the online education reforms for an extended period of time, including many learners who lacked prior experience in online learning. Given that online learning is typically an optional and complementary component in higher education (e.g., Khan Academy instructional videos [145]), the instructors and students who engage in this format tend to possess digital readiness in which they have self-directedness to leverage the flexibility of this form of education to construct their ideal learning environment [91]. ERT, on the contrary, affects all students and instructors with varying personality traits and preparedness, beyond a select few who are digitally ready to partake in online learning.

This descriptive review (as defined by Paré et al. [104]) examines works that offered empirical evidence around socio-technical factors of conducting online classrooms during the COVID-19 ERT. Following a four-step PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [88], we report on a detailed investigation of 22 papers from top HCI and Education research that explored higher education post the COVID-19 pandemic. We report the main findings of our work by grounding them into Moore's classroom interaction framework [89], and discuss two core themes: the long-standing assumption of affordances by designers of educational technology, and a new paradigm of learning that centralizes and augments the student-content interaction.

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2 Background

This section introduces key characteristics of emergency remote education during Covid-19 ERT, presents supporting technology for online synchronous education, and lastly describes Moore's framework of classroom interactions (Fig. 1). The rest of this paper presents empirical evidence from ERT in higher education around the globe and discusses lessons learned for educational technologists and learning-focused researchers.

2.1 Online Education and Emergency Remote Learning

When online education was first introduced as an alternative and complementary mechanism in supporting higher education, many instructors opted for the traditional in-person methods, despite the potential of enhancing scale and flexibility of learning. Specifically, instructors in the mid-1990s were hesitant to facilitate distance education [98] due to a lack of preparedness for translating in-person curricula into online settings [55, 102], as well as limited understanding of general characteristics in remote education [13, 105]. De Gagne and Walters [33] conducted a survey review of distance education works published between 2003 and 2008; they reported that instructors — while recognizing the benefits of online learning — struggled with delivering online lectures due to the time-consuming and high-effort nature of this educational mode, and further desired hands-on training and institutional support.

The worldwide pandemic in 2019 created a massive disruption in all levels of education, and further prompted the majority of instructors to swiftly shift their classrooms into online formats, a phenomenon referred to as Emergency Remote Teaching (ERT) [60]. Over 90% of the global student population (estimated around 1.5 billion individuals) were impacted by the COVID-19 outbreak [129], and soon had to get accustomed to new norms and methods of online learning: students world-wide no longer attended classes in-person or studied at libraries, and some even had to change their learning materials from pen and paper to digital screens [60]. More importantly, students required to pursue a certain degree of self-directedness, given the more flexible learning conditions and limited structure [91]. While COVID-19 was the most recent and significant instance of a global-scale transition in education at all levels, ERT had previously shaped mainstream education, such as during the protests in South Africa between 2015 and 2016 [29] and the spread of the SARS virus in Hong Kong in 2003 [43].

The Covid-19 ERT is a valuable opportunity for educational technologists and learning scientists to explore the authentic experiences of students and instructors in large-scale online education, beyond prior works that predominantly involved individuals in short-term, controlled, and small settings. To fulfill the original promises on distance learning (i.e., meaningfully enhancing access and equity of quality education) it is critical to investigate experiences in long-term, in-the-wild, and large-scale settings, similar to the dynamics shaped by the COVID-19 ERT.

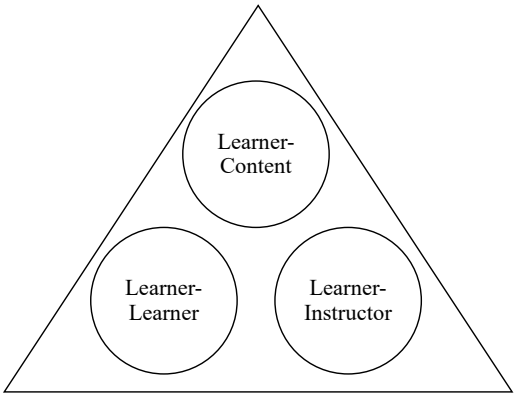

Figure 1: Classroom Interactions Defined by Moore [89]. This taxonomy defines three types of learning interactions: Learner-Learner, Learner-Instructor, and Learner-Content.

2.2 Technology to Support Online Synchronous Education

To support online classrooms, researchers in Human-Computer Interaction (HCI) and Educational Technologies (EduTech) introduced computer-supported tools or studied off-the-shelf systems. A common model of facilitating online lectures is via video-conferencing platforms, such as Zoom Meeting [39, 69], and Microsoft Teams [134, 139]. Other experimental systems aimed to introduce additional capabilities on top of video conferencing. For instance, Chen [25] developed an experimental system that monitored the auditory (e.g., speech) and visual (e.g., hand raise) cues of students to provide an aggregated visualization depicting the pulse of the classrooms.

Other research works experimented with 2D and Desktop-3D to enhance realism and immersion of learning environment. Prior works incorporated Gather, a desktop system that combines video chat with 2D maps and enables nearby users to communicate via video, audio, and chat. These studies increased enjoyment and interaction between students and instructors [85], enabled discussing topics in various-sized groups [45], and facilitated a learning environment similar to a physical classroom [40]. Other works explored the use of Desktop VR in facilitating online learning, not just because of the added flexibility in creating connections, but also due to representational fidelity (or scene realism) that broadly refers to the continuity of the experienced stimuli [140]. Prior work on Desktop VR-based environments reported higher learning outcomes for low spatial ability students in biology education [78], positive effects on learning driving rules [24], improved curiosity and interest in understanding Geosciences phenomena [46], and enhanced academic achievement and satisfaction when learning physics concepts [67].

Adaptive learning systems can help instructors monitor the progress of students in the classroom, as well as introduce synchronicity outside the classroom. Learnta [10] is an online learning platform that uses knowledge-tracing algorithms to select the next learning content that matches the expertise level of the students. Follow-up works provided this data to the instructors who managed to curate the selection of course material for the

entire class: students' learning improved by 17% in mathematics and 25% in English [150]. Other adaptive learning systems connect instructors and learners through content driven conversations, such as ASYMPTOTE (Adaptive Synchronous Mathematics Learning Paths for Online Teaching in Europe) [12]. Developed in Europe in response to Covid-19 ERT, ASYMPTOTE provides an online classroom-like platform for students and teachers to discuss content with various difficulty levels. These adaptive assignments enable teachers to continuously monitor students' progress and offer personalized feedback. Outside the classrooms, adaptive learning systems can complement the main class sessions by providing learning material tailored to students' needs and interests. For instance, Grimón et al. [53] developed an adaptive system that assigns personalized reading plans according to K-means clustering algorithms; students (across three countries) highly preferred this blended learning environment due to having flexibility in learning topics of interest.

As described in this section, many prior works improved learning processes by introducing video conferencing and adaptive learning systems. During the Covid-19 ERT, many instructors around the globe turned to these computer tools to quickly transition their in-person classrooms into online formats. This paper explores these classrooms via a descriptive review and reports on the positive and negative experiences of the instructors and students.

2.3 Three Types of Classroom Interaction

This section presents benefits and strategies of three types of classroom interactions according to Moore's taxonomy [89].

2.3.1 Learner-Instructor Interaction. Class participation is the most common type of Learner-Instructor interaction and refers to any in-class student engagement. This type of interaction leads to enhanced personal and professional development and satisfied classroom experience [52, 59, 64], higher student motivation [66], improved critical thinking skills [27, 51], and better learning outcomes [30, 48, 135]. Many engagement strategies can promote classroom participation, such as instructor-initiated questions aimed to encourage student replies [44, 100], cold-calling (i.e., calling on students without warning) [96], and personal voting systems (e.g., clickers) [109, 120]. Dedicated time before and after the lecture can also provide students with valuable opportunities to engage with their instructor in smaller settings and seek academic and personal advice [146]. However, online classrooms can struggle to implement these Learner-Instructor interactions. First, due to students' unwillingness to share key visual cues [146] instructors—who adjust teaching according to students' emotional and cognitive signals [25, 138]—fail to read their classrooms and implement fitting participation strategies. Second, the remote nature of attendance in online classes can introduce barriers to students' engagement such as distraction [41] and technological difficulties (e.g., weak WiFi signals) [146].

2.3.2 Learner-Learner Interaction. Learner interactions with peers build a sense of community [86] which further contributes to personal and academic benefits, including increased learning [50], better emotional well-being and stress management [108, 121], as well as better persistence and attrition [28]. Some prominent examples of this type of interaction include self-introductions, disclosing personal experiences, discussions with the entire class, and exchanging resources (e.g., notes or techniques) [118, 131]. In online classes, however, few opportunities for peer connection exist, since the main lecture time with all other students and instructor is the only synchronous time for interaction. This can exacerbate feelings of isolation for some students [71]. Especially in traditional video conferencing systems used for lectures, students lack the agency to create smaller and more intimate interactions. As such, remote students can struggle with creating and maintaining social circles during their studies [26].

2.3.3 Learner-Content Interaction. Learner-Content interaction represents the process of intellectually interacting with the learning content to prompt changes in the learners' understanding, perspective, and cognitive structures [89]. This type of interaction is fundamental for education [132] and critical for learning [125], yet it has received the least attention in the literature on online learning due to its broad nature that can vary widely depending on course structure [122, 149]. Prominent Learner-Content interaction techniques include time spent on PowerPoint slides and other educational web pages during class time [122], taking notes, and capturing screenshots of key slides. Facilitating online learning resources in remote classrooms has the potential to enhance delivery, accessibility, and student satisfaction [116], yet these benefits are subject to students' access to a reliable internet connection, and decent computer devices.

2.3.4 Overall Classroom Interactions. Quality education is subject to effective use of all three types of interactions to facilitate unique learning activities, as showcased in Figure 1. Moore [89] further argues for techniques that suit each type of interaction: for instance, video conferencing tools, while great for Learner-Learner and Learner-Instructor interactions, are often used for presenting content which might benefit from high-quality, pre-recorded media [89]. Sole commitments to one type of interaction (via limited techniques) can weaken the educational programs.

3 Methods

In order to robustly examine the empirical evidence for emergency remote learning in higher education, we extracted papers from a diverse set of computer science and learning science venues, applied screening and eligibility criteria, and arrived at 22 total research papers (listed in Table 1). Figure 2 shows this four-step process, inspired by the PRISMA framework (Preferred Reporting Items for Systematic reviews and Meta-Analyses) [88]. The lead author (who is an experienced HCI and EduTech researcher) identified and screened the research papers, and all three authors collaboratively analyzed the final corpus. The authors have attended online classrooms during COVID-19 ERT, as students, teaching assistants and instructors, and observational researchers.

3.1 Identification Process

Given the importance and broad applicability of ERT and online education for different types of subjects, we aimed to target published works from two main disciplines that are well-equipped

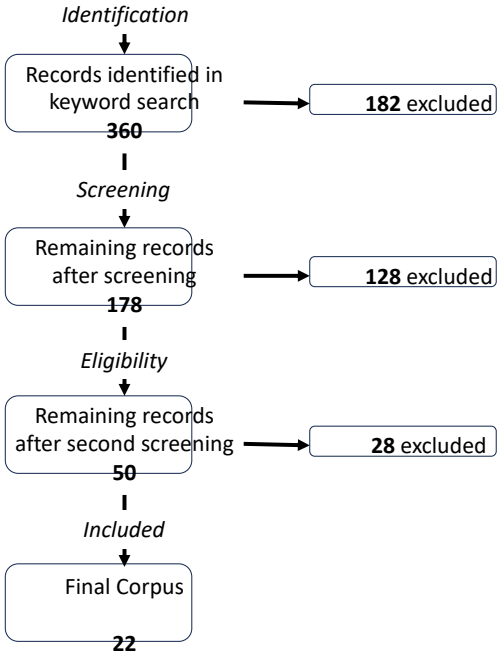

Figure 2: Flowchart diagram representing the four-step selection and refinement process in this literature review, inspired by the PRISMA methodology.

to explore this topic: Education Research and Human-Computer Interaction (HCI), using the Publish or Perish software [57].

Education Research is one of the most-established domains that tackles broad topics in learning and teaching from conceptual, philosophical, and utilitarian perspectives [47]. Education Research — now consisting of sub-disciplines such as educational psychology and learning sciences — is uniquely situated to explore the dynamics of the recent global ERT, draw parallels with traditional in-person and online education, as well as inform future research directions. To include high-quality and diverse publications in Education Research, we selected the top six journals with highest Impact Factors (IF)[1], a common measure for evaluating journals [49]:

- Computers and Education (IF=12)
- Educational Research Review (IF=11.7)
- Review of Educational Research (IF=11.2)
- Educational Psychologist (IF=8.8)
- International Journal of Educational Technology in Higher Education (IF=8.6)
- Internet and Higher Education (IF=8.6)

HCI specializes in the relationships and fit between humans and technological factors [56]. HCI is well-suited to explore education, especially when it involves complex socio-technical components like the dynamics between teachers and students in online education. Since most HCI publications go through a conference format, we used h-index [16] to identify the top six venues[2]:

- Computer Human Interaction (CHI) (h=122)
- Computer-Supported Cooperative Work (CSCW) (h=71)
- Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies (h=63)
- IEEE Transactions on Affective Computing (h=62)
- International Journal of Human-Computer Studies (h=62)
- Behaviour & Information Technology (h=55)

To extract relevant publications from the 12 venues listed above, we adjusted the year of publication and keyword fields of the Publish or Perish software [57]. While the COVID-19 virus was detected in 2019, it was not until early 2020 when WHO announced evidence for human-to-human transmission, in which many countries announced lockdowns and implemented swift shifts to online education [42]. As such, we restricted the retrieval of papers to those which published at or later than 2020. In addition, to extract thematically-relevant papers, we incorporated a number of keywords that the prior work uses to describe online education. The following presents the two sets of keyword queries (total of 15 keywords) used for retrieval:

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(online|live|virtual|remote)(classroom|class|lecture)
(emergency remote)(teaching|learning|education)
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3.2 Screening Process

The screening phase comprised two steps. *First*, we removed duplicate publication entries (N=32) which might have resulted from papers using different keywords to describe the same phenomenon (e.g., online classroom and emergency remote education). *Second*, the first author read the title and abstract of each paper and removed publications that violated the inclusion criteria (as distinctly evident by only reading the title and abstract). These criteria included:

- setting in a higher education institution,
- investigating online education in the COVID-19 lockdown era (e.g., blended learning was not considered),
- exploring synchronous learning and teaching dynamics (e.g., MOOC-related works were excluded),
- contributing via empirical evidence in an in-the-wild study condition (e.g., evaluating "novel" tools in small lab studies was not relevant).

These criteria aimed to align this review with the main goal of the study and surface dynamics of higher education classrooms that shifted from in-person to remote settings. The screening phase excluded 182 papers, resulting in 178 works for the eligibility phase.

3.3 Assessing Eligibility

To assess the eligibility of the remaining papers, the first author applied the inclusion criteria listed above, but considered the paper content more broadly by reading through Introduction and Methods, and marked papers that did not comply with the set requirements. These two sections provide quick, yet robust set of information to assess the eligibility of publications. Non-full papers were also excluded, resulting in a total of 50 papers after removing 128 works.

[1]IFs reflect January 2024

[2]h-indices reflect January 2024

3.4 Final Corpus

The final corpus of the research papers includes 22 works, listed in Table 1. 28 papers were excluded in this phase after reading the entire paper and validating eligibility against the inclusion criteria. Example papers that were excluded in this final phase investigated live-streaming (i.e., asynchronous) and proctoring (i.e., not a bidirectional interaction dynamic). We lastly read and discussed each paper thoroughly to understand the final corpus in depth.

4 Intentions and Findings of the Final Corpus

Two main categories emerged during initial analysis of the 22 papers: one was the intended purpose of the studies, which we refer to as *Research Intention*, and the results reported in the study, which we define as *Findings*. In this section, we outline important themes and patterns found across the two categories.

To investigate which type(s) of classroom interactions the papers in the corpus focused on, we examined the two categories in terms of how they engaged with Moore's taxonomy. We explored *Research Inention* by specifically looking into research question(s), background, methods, and *Findings* by investigating results and discussion. We then assigned each discussed point to the most representative classroom interaction (Table 1).

4.1 Initial Research Direction

When analyzing the paper closely for original research intention, we found that among the 22 papers, nine of them set out to investigate Learner-Content interaction before carrying out the study, four studied Learner-Instructor interaction, while only one focused solely on Learner-Learner interaction. Some papers studied more than one interaction, including four for both Learner-Learner and Learner-Instructor, and one for both Learner-Content and Learner-Instructor interactions. None of the 22 papers focused on the intersection of Learner-Learner and Learner-Content interactions as their original research intention. Three papers studied all three types of interactions. Figure 3 shows

Table 1: Final Corpus of the 22 papers included for analysis in this survey study. The left part describes general characteristics of the corpus, such as main authors and setting. The right part of the survey (Sec.4) present our preliminary investigation by mapping the initial intentions of the paper, and eventual presented findings.

Paper	Study Setting	Perspective (s)	Data Collection Methods (N)	Intention Interaction			Findings Interaction		
				L-L	L-I	L-C	L-L	L-I	L-C
Yarmand et al. [146]	USA	Instructor; Student	Interviews (7 I); Survey (102 S)	×	×		×	×	×
AlShamsi [5]	UAE	Student	Survey (350); Interviews (10)	×	×	×	×	×	×
Ullah et al. [128]	Bangladesh	Student	Survey (214)			×			×
Moster et al. [90]	USA	Instructor; Student	Survey (173 I; 556 S); Interviews (13 I; 15 S)	×	×		×	×	×
Maloney et al. [82]	Australia	Student; Instructor	Interviews (18 S; 10 I)	×	×	×		×	×
Engel et al. [37]	Germany	Student; Instructor	Survey (18,262)	×	×	×		×	×
Nowak and Watt [94]	USA	Student	Survey (200)	×	×	×	×	×	×
Weidlich and Kalz [136]	Europe	Instructor	Survey (102)			×			×
Bruggeman et al. [20]	Belgium	Instructor	Focus Groups (6 with 32 I)		×			×	
Paradeda and Santos [103]	-	Student	Survey (1,011)		×			×	×
Jung et al. [65]	Japan	Instructor	Auto-ethnography (5)			×			×
Iranmanesh and Onur [62]	Cyprus	Student	Survey (185)		×			×	×
Lee and Jung [79]	South Korea	Instructor	Survey (201)	×	×		×	×	×
Dziubaniuk et al. [35]	-	Student	Course reflections (166 essays)		×			×	×
Turner et al. [127]	Australia; Sweden	Instructor	Collaborative Autho-ethnography (5)			×	×	×	×
Kotera et al. [72]	UK	Student	Interviews (19)			×		×	×
Alammary et al. [2]	Saudi Arabia	Instructor	Survey (391)	×			×		×
Ravi et al. [111]	India	Student; Instructor: Admins	Interviews (5I; 3S; 4A)			×	×	×	×
Turan et al. [126]	Turkey	Students	Survey (1,760)			×	×	×	×
Ives [63]	US	Students	Survey (1,731)		×	×	×	×	×
Wu et al. [143]	US	Students	Survey (175; 256)			×		×	×
Wong et al. [142]	US	Students	Survey (633)			×		×	×

the distribution of each type of interaction as part of the initial research direction (left), and eventual presented findings (right).

4.2 Eventual Presented Findings

As indicated in Figure 3-right, the results of papers (under *Findings*) have a distinctly different distribution compared to what the papers declared to focus on in their *Research Intentions*. Three papers (out of 22) studied Learner-Content interactions, one focused on Learner-Instructor interaction, but none investigated solely Learner-Learner interaction. Learner-learner and Learner-Content intersected in one paper, and the same happened for Learner-Learner and Learner-Instructor. Seven out of 22 papers were found at the intersection of Learner-Content and Learner-Instructor. Nine of the 22 papers were placed in the intersection of all three interactions.

4.3 Trending Towards Learner-Content and Cross-Interactions

Overall, when comparing Moore's interaction types in the two categories, we can see two important trends.

The first trend is an increase in Learner-Content themes emerging in the findings, even when not originally planned by the authors of the papers. A potential reason for this unexpected reporting of findings might be the connectedness between Learner-Instructor and Learner-Learner interactions to Learner-Content. Jung et al. [65] studied ERT-derived challenges and the faculty's remedying actions, and noted that one of the biggest challenges for the faculty was "content-related problems (15.1 %)" (page 8); this involved "concerns over the level of difficulty of reading materials" (page 8), which points to a Learner-Content interaction [65]. This example (among others) exemplifies how Learner-Content interaction is a core part of learning and is frequently derived from other interactions.

The second trend was a tendency for papers aiming to investigate only one type of interaction, to then discuss other types of interactions in the findings. For instance, while Ravi et al. [111] originally aimed to study students' attitudes regarding remote content interactions, the results included the influence of attitudes on collaborative activities and communication with peers (Learner-Learner) and instructors' strategies to encourage participation (Learner-Instructor). This trend from *single* interactions to *cross*-interactions showcases the interdependence of the three types of classroom interactions.

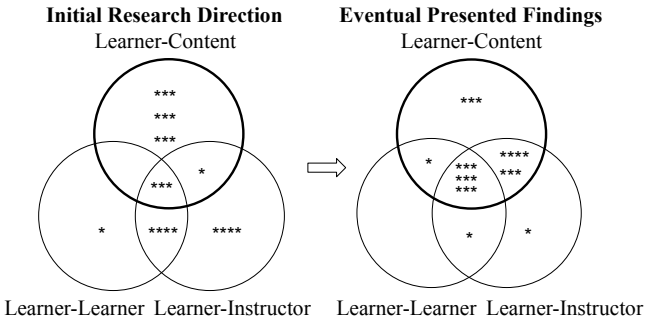

Figure 3: Comparing three types of interactions in the initial research direction vs eventual presented findings. Two trends appear. First, almost all papers end up reporting findings related to Learner-Content. Second, many papers report two or more types of interactions, even if originally not declared.

5 Analysis and Results

Being aware of the overall trends between intentions and findings, we then aimed to investigate main themes in these studies. In this section, we therefore describe key themes extracted from the corpus in relation to each of the three types of classroom interactions defined by Moore [89]. We use Lowenthal *et al.*'s [81] typology of online learning (and select the most representative category) to structure the findings within each type of interaction. While the previous section outlined a quantitative approach on examining the papers in the corpus, this section follows a reflexive thematic analysis [17] in which the creation and development of the presented themes aimed to draw out core ideas in the literature. When presenting quotes from the participants, we highlight the participants' *department*, *years of teaching experience or age*, and *gender* (separated by semi-colon), if this information is available in the papers.

5.1 Learner-Instructor Interaction

We first present core themes of Learner-Instructor interactions.

Instructor Role: Instructors struggled to read the classroom. Many instructors in the ERT era found it challenging to read the classroom and understand students' changing needs during lectures. Visual landmarks from students (i.e., facial, gestural, and postural expressions) that usually inform the instructor about the progress and quality of the lecture sessions [25] were often missing. These visual cues from the students can indicate feelings of confusion and dissatisfaction, in which experienced faculty members can leverage these signals to adjust teaching pace and methods [25, 138]. An example of the impact of missing this information is highlighted by Yarmand et al. [146], who outlined how faculty at a large research university in the US reported missing visual cues from students who did not share their audio and video signals:

> *"When I'm presenting the lecture content, it feels like I'm talking into a void. [...] I'm literally in my own bedroom talking into a black wall and everyone's muted. I have my headphones on, and it's kind of echoey and it feels like I am talking to myself. It became a monologue."* (Computer Engineering; 2 years; M) [146]

Jung et al. [65] reported similar sentiments (via auto-ethnography among instructors in a Japanese liberal arts school) and further reported struggles with detecting emotions even among those who shared their videos: *"one thing I noticed was that most students who appeared on the screen did not show any emotions on their face"* (Educational Technology; 30 years; F).

Similar struggles appeared in smaller educational settings, such as discussion groups as well as hands-on studio sessions. Noting the challenges of observing *"the reaction by the students"* (Linguistics; 21 years teaching; Male), instructors mentioned difficulties *"oversee[ing] which group had difficulty and which group*

went well during discussion" (Public Policy; 12 years; F) [65]. In addition, investigating the design studios in architectural classes, Iranmanesh and Onur [62] discussed the lack of bi-directional communication in remote hands-on critique sessions, stemmed from the inability to read the body language of instructors and students. Informed by visual cues in an in-person architecture classroom, both the students and instructors choose which station to attend. Yet, in a post-pandemic era, the lack of informative visual cues turned students from active participants into passive observers through disjoint shared screens on video conferencing tools [62]. This is particularly problematic for design studios, as bi-directional communication fundamentally impacts the pedagogical value of design studios [36].

Instructor Role: Change in pedagogical actions preceded change in beliefs about online learning. Instructors of emergency remote education adjusted many aspects of the curriculum to better fit the remote context, yet their beliefs about online learning did not change until later.

Factor analysis of survey responses from Korean educators during the early part of the pandemic revealed that instructors made most changes to their behavior and use of the available technologies, yet their beliefs about online teaching changed only slightly [79]. Following the SAMR model of Substitution, Augmentation, Modification, and Redefinition [107], instructors mainly engaged in Augmentation by converting in-person course structures to online versions, while some incorporated a modest level of revision on the course content (i.e., Modification) [79]. Lee and Jung [79] hypothesize that not having reached the Redefinition stage stems from the rapid shift of in-person instruction to remote education in an ERT era.

In the later part of the COVID-19 lockdown, the instructors seemed to have changed general attitudes toward the potential of online learning. To investigate e-learning adoption in Saudi Arabian public universities, Alammary et al. [2] used the Technology Acceptance Model [31] and the Unified Theory of Acceptance and Use of Technology Model [130] to conduct a factor analysis, and found out that self-efficacy and perceived reliability have significant effects on behavioral intention to incorporate e-learning into educational programs. Given the limited preparation time before the swift shift to remote education [3, 60], instructors' self-belief in facilitating online education and the quality of e-learning tools were critical in implementing necessary changes for this transition. Alammary et al. [2] further note that the continuing exposure to these online learning tools (as opposed to early years of the pandemic) positively changed the instructors' willingness to incorporate online learning components in their curricula. These findings are in contrast to existing theories in behavioral psychology — e.g., the Theory of Planned Behavior [1] and the Transtheoretical Model of Change [106] — that suggest change in behavior follows change in beliefs.

Teacher Preparation: Adjusting teaching methods accommodated remote learning. To address the weakened Learner-Instructor interaction during emergency remote education (e.g., lack of communication cues), faculty employed new pedagogical strategies. AlShamsi [5] outlined how during semi-structured interviews at a teaching education program at UAE, one faculty mentioned the importance of *"get[ting] the students focused and on track"* (Instructor), while another expressed repeating concepts for clarity:

> *"repetition is done because sometimes we don't start the instructions the first time, and it is repeated. However, students who disappear and return require more instructions and repetition"* (Instructor) [5].

Another participant of this study acknowledged the benefit of engaging participants in hands-on tasks more than lecture-style talks, especially during remote education: *"the good thing in our class is that we are given more tasks than talk"* (Instructor) [5].

Ravi et al. [111] studied education in under-served communities of India, and reported ways in which the faculty leveraged existing infrastructure to match their strategies of in-person classes. For instance, a 21 year-old student and instructor, explained how he used the rear-facing camera of his phone to broadcast his teaching with better resolution. He later provided an alternative solution for students with limited internet bandwidth:

> *"if they have internet connection problems, I take a screenshot of the solution and send it on the [Whatsapp] group, so that they can go through it. If they do not understand the photo, the student can turn their back camera on and then I guide them on how to solve the question"* (Math; 21 years old; M) [111]

Ravi et al. [111] further frame their empirical evidence to describe a fundamental shift in the Global South education: while previously instructors served solely as *expert knowledge providers*, emergency remote teaching required instructors to also serve as *expert facilitators* who can leverage existing technology to facilitate Learner-Instructor interaction.

Teacher Preparation: Resilient instructors can mitigate weakened Learner-Instructor interaction. Many works studied perceived teaching quality to measure the overall interaction between students and instructors, and reported significant decrease in quality. According to a Europe-wide survey and the follow-up factor analysis on the 102 complete responses, the majority of higher education instructors (76%) reported dramatic drop in teaching quality [136]. Interestingly, the results pointed to noteworthy heterogeneity in the responses, as 19.6% of respondents revealed no change in teaching quality [136].

Investigating the reason behind this large variation in the data, Weidlich and Kalz [136] found that individual characteristics of teaching faculty (like age) can contribute to their instructional resilience during the Covid-19 ERT; psychological resilience describes the ability of an individual to cope with crisis conditions [32]. Prior work has applied this content in education and described ways in which instructors are capable to maintain teaching quality and thrive in delivering lectures [54, 83]. In the post-COVID emergency education era, older lecturers appear to showcase higher resilience compared to younger teachers [136]. While this finding can be counter-intuitive given the shrewdness of the younger generation in a technology-driven education era [11], the higher level of experience and expertise among seasoned instructors can provide more flexibility and judgment in

implementing alternative strategies [4]. Jung et al. [65] corroborated these findings via an autho-ethnographic study in Japan, and further attributed these patterns to the ability of experienced lecturer to scaffold knowledge around unforeseen teaching challenges [76] and learning needs [137], and incorporate high degrees of optimism to boost general attitudes towards education at uncertain times [15].

Multimedia: Modalities with lesser richness enhanced anonymity. Unlike traditional classrooms where in-person attendance is the predominant form of engagement, online learners can choose the modality of participation, ranging from media with higher expressivity (e.g., video) to text which can lack richness, but instead offers higher anonymity.

For instance, several post-COVID studies pointed out the benefit of using the *chat* communication mechanism during lectures. Reporting on the results of six focus groups with 32 instructors at a Belgium university, Bruggeman et al. [20] provide evidence for instructors' appreciation for text-based communication, such as: *"in my online courses, students indicated that they greatly appreciated online interaction through questions in the chat, and online assignments"* (60 years old; M). Instructors at Swedish and Australian universities shared similar sentiments around chats, and further highlighted the potential of text-based features in promoting participation among introverted students: *"some of the positives were that many students who would never raise their voice in a big lecture could now ask questions via the chat"* (Special Education; senior lecturer; F) [127].

Communication: Class engagement dropped gradually due to fatigue. Many studies reported that online class engagement was not only lower than traditional in-person classrooms, but also students expressed a continuous drop in engagement levels as the semester progressed, mainly due to fatigue. Maloney et al. [82] reported how first-year Arts students in an Australian university, felt overwhelmed in the latter half of the semester:

> *"I physically could not do all of the content and that was quite overwhelming when you hit that week six or seven and you're just like, oh my goodness, I haven't done anything, but that's not true. Then it starts to feel like you're not going to do well for the next bit so I would say that is fatigue."* (Arts; 1st year undergrad; F) [82]

At times, students revealed intense feelings of fatigue in online classrooms, contributing to desires for complete disengagement from their programs: *"I shut down personally. I'm quitting. There was lots of times where I actually reached out to the university and said, can I please defer? "* (Aviation; 1st year undergrad, F) [82]. The instructors also reported significant drop-offs in engagement, and attributed this challenge to overwhelming communication between students, university admins, and teaching staff:

> *"StudyDesk [a virtual classroom platform] is overwhelming. The students get a million messages from the university now, like emails and messages. There's more and more stuff that we're encouraged, as educators, to put on our StudyDesk. So, they become more and more busy."* (Rosemary, instructor) [82]

Reflecting on the fatigue-related challenges of students in remote education, Maloney et al. [82] discussed the expectation for students' constant presence. To maintain a Learner-Instructor relationship similar to pre-Covid in-person era, students were required to display explicit engagement with the teaching staff. This added stress and exhaustion of participating in online classrooms has been referred to as *Zoom fatigue* [9, 92].

In the same study, four faculty (out of 10 who participated in interviews) discussed students' varying autonomy and unique learning strategies that might have contributed to the lack of class engagement [82]. A nursing instructor suggested that students are *"quite strategic about what they do and do not do"* (Nursing, senior faculty; F). An Engineering faculty member shared similar sentiments, and further pointed out that the flexible structure of learning content has enabled students to pursue a path that is compatible with their learning and personality, even if this entails minimal levels of engagement with instructors.

> *"I just want to get my course curriculum, submit my whatever I've got to submit, get 100 per cent, because that's what I like to do in these courses, and to heck with having to interact with anyone."* (Engineering; senior faculty; M — spoken in a student's voice) [82]

Other faculty interviewees further mentioned that to enable a flexible learning environment — in which, students can pursue learning in a way that fits their lifestyle — the university instituted a policy that all course material was available on the learning management system for access from the first day [82].

Student Collaboration: Clear goals and regular check-ins boost breakout room engagement. Facilitating breakout rooms is a common pedagogical strategy in order to engage learners in small and student-centered discussions. Breakout rooms leverage the active learning framework [87] in order to promote collaborative learning via breaking down the large number of lecture attendees into small subgroups [80].

Defining clear learning goals enhances to the students' engagement in breakout rooms. A survey study with more than 500 undergraduate students at US universities revealed that students' participation in breakout rooms correlated with having clear objectives [90]. Vague directions (e.g., "discuss chapter 2") hinder students' confidence in achieving the set goals, which in turn discourage sharing audio and video in order to facilitate productive collaborations [73, 95].

Both students and instructors reported that regular check-ins also improved the effectiveness of breakout room discussions: a Biology instructor (with 30 years of experience) mentioned that:

> *"you've got to visit those [Zoom breakout] rooms much like you would if you had the breakout groups in a lecture hall, you've got to bounce in the hall and talk to everybody."* (Biology; senior faculty, F) [90]

Highlighting the challenges of checking in with disjoint groups in online settings, some instructors employed alternative strategies of monitoring breakout room discussions: one notable method was leveraging a shared collaboration tool with a checklist of deliverables (e.g., Google Docs) and tracking students' progress all in one place [90]. The majority of students (68.4%) indicated

occasional (or more frequent) breakout room check-ins by their instructors and found it beneficial for keeping all discussion members on track [90]. The students, however, further shared privacy concerns when missing the cues of an incomer (i.e., instructor entering the breakout room). Aligned with the visibility principle of social translucence [38], Moster et al. [90] also report that the lack of social cues can discourage vocal participation when intrusion to the conversation is possible at any moment.

5.2 Learner-Learner Interaction

This section presents core themes relating to the interaction between learners and their peers.

Multimedia: Personal and privacy factors discourage broadcasting videos. Many research works reported students' reluctance to share videos during lectures. According to a survey study at a large US school [146], some students expressed discomfort with broadcasting (at times) leisure attire and miscellaneous activities to the entire class, such as one student highlighting lack of desire to *"show [their] face when [they] are in home clothes and haven't showered"* (student). In addition, AlShamsi [5] report that privacy concerns led to hesitance in sharing videos, as students might take screenshots of the lecture and share on social media. This uneasiness was explained by a student in a teacher education program:

> *"I think some students hesitate to use the camera and microphone because they don't want other students to record them due to cultural consequences."* (Teacher Education; 1st year student) [5]

Meanwhile, this apprehension for sharing video feeds tend to cease when more and more students choose to turn on their camera and microphone. Incorporating factors of self-usage and other-usage of the video camera, Wu et al. [143] found evidence for social conformity, in which students are more likely to share videos when their classmates turn on their cameras as well. Higher self-usage, in turn, lowers perceived anonymity which might be incompatible with students who self-rate higher in shyness [6].

Student Collaboration: Students felt social loafing and lack of participation in breakout rooms. Despite successful past examples of implementing breakout rooms in the COVID ERT era [70, 115, 124], in-depth interview studies revealed important challenges in breakout rooms. Moster et al. [90] conducted a mixed-method study to investigate collaboration among student groups in higher education online classrooms, and reported a general lack of participation from the majority of students, especially those who are fatigued or might have negative attitudes towards breakout rooms. A sophomore computer science student elaborated on the challenges of initiating discussions:

> *"whenever a teacher mentions the word breakout rooms, everyone goes into a panic, like, no, we don't want to. They're not inherently fun. I get why they're used. But, it's always that worry of, are people going to start talking? I didn't like the waiting game of who's going to talk versus someone going to turn on the camera, who's going to unmute, it's a waiting game. And a lot of people don't want to play it and they just don't do anything."* (Computer Science; senior undergrad; M)

Moster et al. [90] further describe social loafing as a root cause for the lack of participation among online students. Originated from social psychology, social loafing refers to a decrease in individual effort given the social presence of other group members [77].

To enhance the productivity of breakout rooms (given the observed lack of accountability and participation) some students shared taking on ad-hoc leadership roles to promote equal participation: *"I think the most engaged I ever was in a breakout room... It's when you're the leader, so you have to participate"* (Computer Science; junior undergrad; M) [90].

5.3 Learner-Content Interaction

This section presents core themes describing the interaction between learners and the educational content.

Pacing: Many students benefited from the added flexibility of interacting with educational content. Emergency remote education post the COVID-19 breakout facilitated an unprecedented degree of flexibility, in which students pursued (to varying extent) independent learning tasks, without the involvement of their peers and instructors. Many empirical works suggested that the higher autonomy in this era of education did not hinder learning, and instead, benefited students, especially ones (1) attending senior years of their degrees, (2) possessing self-directed learning characteristics, (3) engaged with ill-formed and subjective-leaning topics, and (4) having disabilities.

(1) Seniority — Acknowledging the reality of online education with more self-directed learning opportunities, instructors provided temporal flexibility for students' engagement with the learning content. Bruggeman et al. [20] report how in a focus group at a Belgian university, an instructor explained her changes to increase the ease-of-access for interacting with educational material (in the form of watching lectures and re-taking exercises):

> *"I allow the students to revise content through online learning paths, to make sure they're on board. The fact that learning paths are asynchronous makes it easy for them to rewatch lectures whenever they want. They can go through the footage several times, and they've got retakes and opportunities to redo exercises."* (Associate professor; F) [20]

While incorporating autonomy in online learning was generally successful in higher education classes (especially among senior students), instructors reported concerns with junior students: *"some of the first-year students missed the digital boat completely. They get lost in everything available online"* (Full Professor; F) [20]

(2) Self-directed Characteristics — Investigating architecture design studios under virtual settings revealed misalignment between architecture teachers and students, especially students with self-dependent skills. Prior work in architecture suggests tensions between students — who tend to possess fluency in computer-supported tools and interactions — and instructors who might not have the same skill set and fall back on traditional methods of in-person teaching [19, 34]. Iranmanesh and Onur [62]

observed similar patterns as students managed to adapt to virtual studios more seamlessly than the instructors, and further noted potential for self-dependent students to pursue new learning approaches. Yet, Offir et al. [97] showed that more extroverted learners (who thrive on stronger human-human interactions) might also suffer from the higher autonomy in online education.

(3) Unstructured and Subjective Topics — Students appreciated the additional autonomy in online settings, especially when engaged with subjective and unstructured learning tasks. Dziubaniuk et al. [35] explored the topic of Sustainability Development (SD) in a business class via text-based analyses of students' reflections and reported benefits of independent learning for a topic like SD with fast-changing knowledge that lack gold-standard solutions As a student reflected, *"there are no one single correct answers, but one has to build one's own truth [about sustainability in business]"* (undergraduate student) [35]. The students further noted leveraging fast-paced search and retrieval of current information to arrive at their unique solution: *"I have truly found some good [online] resources for gathering new information on the subject and will continue to study"* (undergraduate student) [35]. Afforded by ERT, fast access to new information is a new normal and a critical skill in learning complex topics [117] which further develops analytical assessments [93].

(4) Disabilities — The swift shift to online learning not only yielded less severe educational impact for students with disabilities, but also promoted much-needed flexibility in pursuing learning and alleviated the existing stigma. Kotera et al. [72] conducted an in-depth interview with 19 students who had various disabilities (e.g., dyspraxia and ADHD) and noted students' appreciation for the opportunity to pursue autonomous learning: *"I like studying online as it gives me flexibility. I usually inform my tutors when I am not active or engaging in the forum owing to my disability."* (Psychology; graduate student; F). Following a retrospective pretest study design with doctoral students at a large university in the USA, Ives [63] found that students with disability-related conditions had significantly less drop in engagement after the shift to online education. These studies showcase that students with disabilities can particularly benefit from the flexible nature of online learning, as each student requires a curated set of learning content with unique learning pace.

These students further shed light on the stigma around attending classes (and the perception from their peers and instructor) while having disabilities. One student noted this challenge in the interviews conducted by Kotera et al. [72]: "*sometimes my condition is very bad, so [I] cannot be active on the forum. I do worry how I may come across to other students as not being active in the forum"* (Psychology; graduate student; F). However, the students further indicated a level playing field when transitioned into online education as their limited interaction with other students and instructor became less apparent:

> *"I think there is perhaps less stigma towards disabilities in the online classroom as it is harder to recognize if somebody suffers from a disability, especially a physical one"* (Computer Science; undergraduate; F). [72]

Kotera et al. [72] further report that the existing feelings of stigma can turn into alienation and isolation for students with disabilities. Online learning shows potential in this regard, given that the lower alienation and isolation can mitigate feelings of loneliness [114].

6 Discussion and Future Research

This section first describes the misalignment between features of educational technology and needs of learners, and later argues for a learning paradigm that augments Learner-Content as the core interaction of online education.

6.1 Feature Misses of Educational Technology

Despite decades of research in online education, when faced with a large-scale shift to remote education, the existing technologies performed subpar in creating productive interaction between remote students and instructors. As reported in the empirical evidence in this work, when given the choice of modality in class participation, many students opted in for less rich and more anonymous types of media, such as text-based chat. This diminished real time feedback and visual cues for the instructors who then struggled to read the classroom and adjust teaching pace and strategies accordingly. Students also desired more flexibility to accommodate for personal and social factors in remote learning (e.g., living with family), yet synchronous lectures via video-conferencing platforms — which required continuous online presence — remained the main method of delivering education and further contributed to online fatigue as the semester progressed.

The empirical evidence points to a mismatch between the features of tools designed for learning, and the actual use of these features by end-users in the real world. We refer to this gap as the "*missed features"* Here, we illustrate three examples of this mismatch, according to the three types of classroom interactions:

Learner-Instructor Interaction — As presented in this paper, students selectively choose how to attend the classroom sessions, and in cases, entirely dismiss existing features. Figure 4 demonstrates an example of this concept: the top image shows a lab study in which students are sharing their video feeds while directly facing the camera in well-lit rooms. In this case, the proposed and tested system can read clear visual cues and provide aggregated signals to the instructor [25]. The bottom image, however, displays typical online learning during the COVID-19 pandemic: most cameras are off, everyone (except the instructor) is muted, and students tend to use the chat feature to interact with their peers and instructor [146]. The features that were originally designed for experimental online learning systems (e.g., the way that video cameras are used in Chen's study [25]) seem to not apply beyond small and controlled settings.

Learner-Learner Interaction — The unstructured time before and after every in-person lecture (i.e., *hall time* [99]) is a valuable time to build interpersonal relationship with the instructor and peers. Yet, these impromptu moments are not accounted for in online classrooms; instructors start the meeting and (after some time) end the meeting, for everyone. After all, the feature that enables ending a meeting altogether is an efficient way of concluding a gathering, at the cost of missing out on much learning. While prior work

attempted to facilitate these opportunities via free-roam tools like Gather [147], popular video conferencing systems lack supporting hall time. This points to another example of mismatch between what students need in realistic settings, and what many educational tools offer to support learning.

Learner-Content Interaction — As noted in the results, the added flexibility of online learning especially benefits students with disabilities as their stigmas become less visible compared to in-person settings. Video conferencing systems, however, tend to prioritize individuals with visible engagement metrics: for instance, learners who share their videos are brought up to the queue of participants, and thus, receive more attention from their instructor; students with their cameras off might then be perceived as lurkers. These gallery formats, while enabling quick overview of all participants, might bring unwanted consequences for students who seek more flexibility.
As such, many developed interaction *"features"* might not benefit the way that they were originally envisioned by designers of educational technology, and ultimately, *"missed"* by instructors and students in realistic settings.

Careful design of learning technology — according to unique needs of learners and the characteristics of the learning topic — has the potential to meaningfully change the educational experience by enhancing engagement while reducing fatigue. There is no guarantee that the sole existence of technology with certain features will indeed improve student engagement [22], and worse, ill-designed platforms can lead to disengagement and further diminish learning [61, 119]. For instance, Hewson [58] calls on designers of educational tools to recognize that the online scene is inherently different than physical learning, and simply replicating the classroom-style education can lead to content-publishing mentality by providing the same learning content and strategies as in-person education. In addition, educational technologies that aim to increase engagement might impose unwarranted cognitive load on the learners [123] and lead to long-term fatigue. Prior evidence shows that excessive content (e.g., too many links and tools [148]) can overwhelm learners and contribute to *learning weariness*: loss of interest in studying due to sustained tiredness towards learning, usually embodied as feelings of boredom and guilt [133].

6.2 A New model for Learner-Content Interaction

To facilitate flexibility in online learning, while providing expert structure as scaffolding, we propose a new model that centralizes Learner-Content interaction and augments it with Learner-Instructor and Learner-Learner interactions. In this model, shown in Figure 5, *Learner-Content interaction* is the core component of learning which enables high levels of learner flexibility in pursuing unique educational paths. In fact, this is aligned with Moore's original vision [89] that refers to this type of interaction as *"the defining characteristic of education [in which] without it there cannot be education"* (page 3). Prior work has (by large) neglected this interaction type due to its broad nature that depends on unique course structures [122, 149].

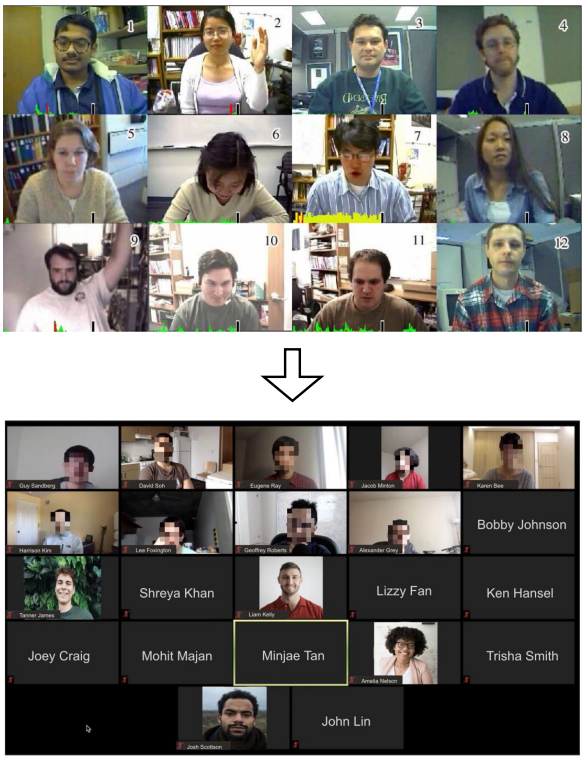

Figure 4: Difference of educational technologies developed and tested in controlled experiments [25] (left), and how students use these features in real-life setting [146] (right).

Besides the empirical evidence (offered in this paper) pointing to weakened *Learner-Instructor interaction*, in large-scale online ERT education of the post-pandemic era the role of instructors might be shifting towards content facilitation and guidance, as opposed to solely delivering knowledge. As presented in the Results section (Sec. 5), this is especially prominent in unstructured and subjective topics that lack gold-standard solutions, such as design studios in architecture classes and sustainability development in business curricula. While this is evident more so than ever — given the

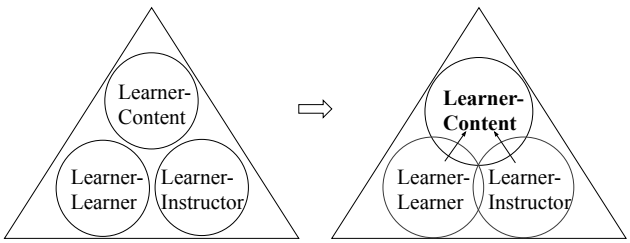

Figure 5: The current model in most educational programs inspired by Moore's framework [89] (left) vs the proposed model of learning interactions in online settings that centralizes Learner-Content and augments it with Learner-Learner and Learner-Instructor (right).

complexities in today's learning subjects — researchers in the 90's also challenged traditional teaching roles aligned with this vision. Rancière [110] argued for *"learning without a master explicator"* (page 130), meaning that the main role of teachers should be to empower self-learning abilities of students, a skill that can provide lifetime benefits. Specifically for architecture education, Attoe and Mugerauer [8] described an excellent educator as a parental and non-authoritative figure who participates in students' unique learning processes via dialectical discussions. As such, the Learner-Instructor interaction can serve as valuable resources that guide Learner-Content interaction and cues learners to focus on the right learning content at the right times.

As learners need more flexibility in study time during remote learning, Learner-Learner interaction might no longer fit as a core form of learning. With similar weakened dynamics between students and instructors in remote learning, Learner-Learner interaction can augment Learner-Content interaction to help guide learners in finding and digesting content that benefits their unique learning needs. Peer learning (e.g., peer feedback [75] and peer assessment [74]) and commentary discussions among peers about online courses content [145] provide valuable information that can inform scaffolding learning, an instructional practice in which guidance is given to learners in the beginning but is removed gradually to help learners build competence in content and skills.

While centralizing one type of interaction (and augmenting it with the other two) might seem counter-intuitive, as it can entail fewer interaction opportunities with lesser extent, prior research argues that not all interaction types need to be offered at similar levels to achieve satisfactory learning outcomes. Anderson's Equivalency Theorem [7] states:

> Deep and meaningful formal learning is supported as long as one of the three forms of interaction is at a high level. The other two may be offered at minimal levels, or even eliminated, without degrading the educational experience.[7]

As discovered in subsequent studies that aimed to evaluate this theorem [101, 112, 113], while there is evidence that increase in one type of interaction can compensate for the decrease in the other two, it is unclear whether one type can entirely substitute another [144]. Our model specifically provides a pathway for this theorem, in which Learner-Content is the main type of classroom interaction (that is fully supported in online learning environments), while Learner-Learner and Learner-Instructor can be offered at minimal levels to enable balance between flexibility and structure.

6.3 Limitations

This literature review contained a relatively small subset of existing venues in computer science and learning science which might have led to a limited diversity of findings. Selecting the top venues in each discipline, however, enabled incorporating rigorous and high quality research. In addition, this paper deviated from providing an exhaustive list of findings from the corpus of papers, a common practice in many literature review studies. Instead, via a reflexive thematic analysis approach [17], we created themes that note our unique expertise in learning interactions, and highlighted specific lessons for HCI and learning sciences.

7 Conclusion and Lessons Learned

The Covid-19 pandemic in the 21st century resulted in an unprecedented and large-scale shift to online education. Many instructors who had never conducted online classrooms had to swiftly modify content and teaching strategies. Students also had to quickly adapt to the new learning environments, including many who lacked digital readiness skills. The empirical evidence from 22 papers (published at top HCI and Education research venues) pointed to weakened Learner-Instructor and Learner-Learner interactions, and strategies that the instructors used to mitigate these interaction gaps. On the other hand, many learners appreciated the added flexibility offered in online education, especially the senior students who were enrolled in classes with unstructured activities and subjective-leaning topics.

We discussed that the mismatch between features of online learning technology and students' needs is a main contributing factor for subpar levels of engagement. We also introduced a revised model of classroom learning interaction that centralizes and augments Learner-Content as the core type of interaction in order to balance between structure and flexibility of online education. Based on our findings, we offer the following two broad lessons to apply to future educational technologies,

- *Designers* of remote educational technologies should consider the societal and cultural norms of online education in the real-world which can differ significantly from in-person classroom settings. For example, online learners (who particularly value higher anonymity in order to separate personal and professional lives) might not prefer video-based communication. As such, technologies can aim to develop tools that, while maintaining learner anonymity, provide key visual cues to instructors for better class management.
- *Learning Researchers* should more intentionally study Learner-Content interaction as a core component of learning interactions, and further explore how it can be augmented by Learner-Learner and Learner-Instructor interactions. Specifically, deeper engagement with cognitive processes of learners can reveal important implications for later incorporating instructors' key expert lessons, and peers' varying learning processes.

We hope that the interpretation of the existing literature, and the future direction offered in this work can facilitate effective planning, designing, and developing new educational strategies as the threat of pandemics (and the mitigating ERT measures) remains a likely outcome in the future.

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