eLmL 2025

The Seventeenth International Conference on Mobile, Hybrid, and On-line Learning

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eLmL 2025 Editors

Gerhard Hube, Technical University of Applied Sciences Würzburg-Schweinfurt, Germany

eLmL 2025

Forward

The Seventeenth International Conference on Mobile, Hybrid, and On-line Learning (eLmL 2025), held between May 18th, 2025, and May 22nd, 2025, in Nice, France, continued a series of events bringing together federated views on mobile learning, hybrid learning, and on-line learning.

eLearning refers to on-line learning delivered over the World Wide Web via the public Internet or the private, corporate intranet. The goal of the eLmL 2025 conference was to provide an overview of technologies, approaches, and trends that are happening right now. The constraints of e-learning are diminishing, and options are broadening as the Web becomes increasingly easy to use and the technology
becomes better and less expensive.

The event provided a forum where researchers were able to present recent research results and new research problems and directions related to them. The topics covered aspects related to tools and platforms, on-line learning, mobile learning, and hybrid learning.

We take here the opportunity to warmly thank all the members of the eLmL 2025 technical program committee, as well as all the reviewers. The creation of such a high-quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and effort to contribute to eLmL 2025. We truly believe that, thanks to all these efforts, the final conference program consisted of top-quality contributions. We also thank the members of the eLmL 2025 organizing committee for their help in handling the logistics of this event.

We hope that eLmL 2025 was a successful international forum for the exchange of ideas and results between academia and industry for the promotion of progress in the field mobile and on-line learning.

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Hybrid Harbors: Immersive Learning Spaces for Unsafe Regions

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***Abstract*—This paper focuses on hybrid classes as immersive learning spaces for unsafe regions. This study explores the technological and anthropocentric challenges and solutions associated with hybrid-format learning in an unsafe region (Ukraine). The paper is based on the experiences gained during hybrid seminars on Teaching English as a Foreign Language (2022/2023) for student teachers from Germany's Julius-Maximilians-Universität Würzburg and Ukraine's National University "Zaporizhzhia Polytechnic". Technological limitations, solutions at-hand, and perspectives for further development of "hybrid harbors" based on the Activity-Centered Analysis and Design are considered.**

Keywords-hybrid; physical, epistemic, and social aspects of learning; tech pods; empathy and resilience.

I. Introduction

In the evolving landscape of education, Hybrid-Format Learning (HFL) emerges as a postdigital learning space, blending digital and physical environments. This study explores the technological and anthropocentric challenges, as well as solutions associated with HFL in an unsafe region. Participants of HFL seminars on Teaching English as a Foreign Language (TEFL) (2022/2023) future EFL student teachers from Germany's Julius-Maximilians-Universität Würzburg and Ukraine's National University "Zaporizhzhia Polytechnic". The Ukrainian University is situated close to the front line and periodically suffers from shelling that damages its buildings and makes classroom learning impossible. Some students and teachers have fled the region or the country to find safer living conditions. Those who stayed are constantly experiencing electricity disruptions due to ongoing military conflict actions in the country. The only way to continue education and maintain a high level of students' engagement in the current situation is to have online classes.

The necessity of a safe digital learning environment during crises, such as the ongoing war in Ukraine, is indisputable. Working together in an HFL environment, which was urgently designed with the elementary technologies available (laptops and a projector), German and Ukrainian students had the possibility to foster their professional competencies, emotional intelligence, empathy, and resilience. To avoid "a feeling of loneliness in a hybrid-format environment that can be harmful as smoking one box of cigarettes a day" [1], their teachers fostered trust and safety by bringing all voices into the room through a network of interrelated topics and dialogues.

The rest of the paper is structured as follows. In Section II, we present the background of this study. In Section III, we focus on the chosen methodology. In Section IV, we present the main findings and discussion. Finally, we conclude in Section V and provide some future perspectives.

II. Background of the Study

Despite technological limitations, such as overloaded learning management systems, software constraints, student frustration with technology, sound failures, memory availability issues, and unstable internet connections, especially in an unsafe region [2] - [6], solutions at-hand were implemented. At this point, Miro whiteboard and/or Etherpad were used on a continuous basis. Additionally, despite the use of a single camera in the onsite classroom and the individual cameras of students in their cell phones, laptops, and other gadgets, missed discussions, visual cues, interactions, audio interruptions, and microphone issues hindered effective communication between online and face-to-face students. However, the students were provided with constant access to learning materials, group work, and discussion output was offered before and after HFL seminars.

To address these challenges, the study recommends comprehensive training in technology and course management [7], strategies to enhance the learner experience and technology design [8] - [10]. Solutions include equipping classrooms with multiple cameras and high-quality microphones to capture all interactions and voices, thus fostering a more inclusive and dynamic learning environment. Ergonomic limitations also pose significant challenges, as lecturers often find themselves tethered to computers, reducing their mobility and engagement with students. The study suggests that both teachers and students should have the flexibility to move freely within the classroom to facilitate group work and engage in a more interactive learning process. However, technologies and equipment should be modified and settled accordingly, for example, to "catch" teacher's movements in the classroom or capture the faces and voices of the onsite session participants. The inclusive, friendly, and flexible learning environment should host and nurture both students and teachers. For example, some teachers, invited speakers, and students have experienced either forced or voluntary displacement in their lives, and finding themselves together within a "hybrid harbor" helped them to tie themselves closer to each other rather than experience a feeling of alienation.

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III. METHODOLOGY

A. Activity-Centered Analysis and Design

The implementation of the Activity-Centered Analysis and Design (ACAD) framework fostered the physical, epistemic, and social aspects of learning [11]. It was chosen as a practical guideline to solve challenging learning situations, namely "…Activity-Centered Analysis and Design (ACAD) is a meta-theoretical framework for understanding and improving local, complex, learning situations" [11].

Following works on ACAD, we realize that in order to achieve better learning outcomes, teachers need to carefully plan not only the content and forms of assessment but also take into consideration the learning environment. Therefore, we further consider "*activity*" as any engagement of students in the learning process (mental, physical, or emotional). The "*learning situation*" also comprises three abovementioned components, as during hybrid seminars they were placed in different locations (onsite/online; in groups/individually; mixed locations). The "*complex*" nature of analyzed hybrid seminars, following the developed scenario based on ACAD framework, is further interpreted from both experienced and future views. Within the scenario, the "complexity" of the studied learning situation was solved within five main conceptual blocks: building understanding and connection, emotional support and resilience, enhancing empathy in peers, educational engagement, cultural awareness, and sensitivity. The offered scenario highlights psychological, emotional, and communicative aspects of HFL, tending to provide a holistic learning environment.

The following table (Table 1) represents the average number of hybrid session participants.

TABLE I. AVERAGE NUMBER OF HYBRID SESSION PARTICIPANTS

Participants (average number per session)	**Onsite**	**Online**
6 hybrid Sessions (2022/23)		
Students	13	17
Teachers	1	1
Guest Speakers	2	4

Following the ACAD framework, the paper represents a specific scenario for the hybrid classroom with the main focus on an unsafe region. The scenario includes epistemic, set, and social design. The epistemic design refers to the assignment the students received before the seminars and the activities they were supposed to be involved in during the hybrid session. At this stage, the topics for the seminars were carefully selected so that they would not raise negative emotions, but would encourage students to discuss sensitive topics and find solace or solutions in the suggestions provided.

The set design includes materials and platforms for interaction, presentation, sharing and visualizing ideas, multimedia, etc.

The social design presupposes the planning of the ways students interact during the hybrid session. Ukrainian students from frontline cities have been living in conditions of social distancing for five years already. The feeling of alienation is exacerbated by disrupted relationships due to displacement, uncertain prospects for the future, and worries about their relatives' lives.

Hybrid seminars aimed not only to share knowledge on teaching English as a foreign language but also to establish networks and improve Ukrainian students' emotional state through peer collaboration in virtual settings. An opportunity to communicate with German students made Ukrainians feel that they were not outsiders struggling with their problems unsupported and that they belonged to a community that shared their values and had similar viewpoints.

Creating a learning design considering all pedagogic properties can be facilitated through visualization. For such a purpose, the tool "Learning Designer" was used [12]. Each step of the hybrid sessions was specified in terms of learners' activities, teachers' involvement, duration, and resources to be used. The pie chart in Figure 1, which is generated from the information provided, illustrates the different types of learning and student interaction, allowing the teachers to analyze the effectiveness and patterns of students' participation and make adjustments before the seminars.

B. Scenario of the Activity-Centered Analysis and Design (ACAD) Framework for Hybrid Classroom in Unsafe Region

1) Background scanning

Focus on Context: safety issues in the region were identified (e.g. due to electricity and Internet disruptions, the seminars could be rescheduled, and all necessary digital materials were available);

Needs of Students and Teachers: social concerns and the emotional condition of the target audience, which can influence the class were considered (e.g. preparatory virtual phase for teachers – advanced meeting for planning the session; a constant channel for communication, such as Messengers, scanning the psychoemotional conditions, potential preventing factors of students and reporting about that to a colleague teacher).

2) Hybrid Classroom Design and Implementation Steps

Flexible and adaptable: discuss possible adaptations in case safety background conditions are violated (e.g. sharing video recordings and students' self-presentations on Flipgrid; recording voice messages and creating groups on Messengers for Session participants for instant communication);

Accessible and reliable: provide relevant technologies (open sources, free, and easy to use; e.g. create guest accounts for Miroboard, use Zotero as an open and free accessible digital library for sharing learning materials and enabling students to upload the materials themselves; an important option of offline access and asynchronous use of provided resources);

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3) *Hybrid Classroom Learning Process Design*

Blended Learning: provide an option to learn both synchronously (live classes) and asynchronously (recorded lectures, online assignments);

Collaborating Learning Tools: interactive whiteboards, collaborating tools, such as Wooclap, Wordcloud, Mentimeter, etc. to facilitate students' interaction with an option of post-session access;

4) *Technologies Used*

Flowing Communication: despite the breakages and blackouts, students have access to supporting communication technologies (e.g. use of power banks to charge their gadgets), accessible asynchronous learning materials;

Secured and certain: beware of cybersecurity issues and be ready to withstand the online threats (e.g. online support and instant messaging with volunteering IT specialists and/or IT competent students was at hand).

5) *Sustainable and Resilient Learning Environment*

Mental Well-being: offering workshops and activities, that enabled students to withstand their emotional strain (e.g. implementation of a slow-looking method, integration of artful and pedagogical practices; addressing empathy and resilience with at-hand experiences; reflecting on students and teachers' own experiences);

Build Up the Community: interaction of students during collaborative projects, communication during and after the seminars, and extracurricular communicative activities (e.g., participation in the evening's Multilingual Speaking Club).

6) *Evaluation and Feedback*

Sustaining Improvements: regular meetings between teachers before and after the seminars, communication via emails and/or Messengers, feeling supported and providing support to each other enable continuous modifications of the hybrid format seminars based on regular feedback from all parties involved (students, teachers, guest speakers);

Survey and Data Collection: short questionnaires during pre- and post-seminar phases with a flexible deadline were provided to all parties involved. Open questions option enabled students to reflect on their own experiences, feelings, and concerns, interests, ideas, and changing the role from the recipient of knowledge to the initiator and disseminator of self-authored seminar activities, learning materials, and scenarios.

IV. Main Findings and Discussion

A. *"Hybrid Habors" as versatile collaborative spaces*

According to post-session survey data: "TEFL: Inter/transcultural learning and global education", the participants reflected on the commonality of their thematical foci, confirming creation within "hybrid harbors" of "a *collaborative learning environment* that encourages active participation, using hands-on activities and projects that promote authentic language use" (anonym. Session participant) and their ability to "demonstrate qualities like cultural awareness, empathy, and a willingness to engage in issues that transcend national borders" (anonym. Session participant). The hybrid classroom enabled students from Ukraine to be closer not only to the students but also to the invited speakers from different countries. For example, the speaker from Ukraine (internally displaced) took part in the Session on *Multiperspective Representation of Cultures via Various Texts and Media*. The Session on *Skills, competencies, and strategies in TEFL* with an intercultural focus featured a speaker from Spain. The seminar on *Arts and Pedagogy*, specifically the slow looking method in TEFL classes, was led by a speaker from the Czech Republic. The speaker from Canada was invited to the Session on *Materials and Introducing data-driven EFL*. A professor from India was invited to the Session on TEFL basics, focusing on *transnational insights and interdisciplinary ties*.

Such a versatile palette of speakers enabled the students to collaborate beyond the borders of cultures and realities, as their interactions were released through synchronous discussions and interactions with the invited international speakers using an interactive whiteboard, as well as they had access to it during a post-phase of the sessions. Thus, despite their locations (either internally displaced in Ukraine or abroad), the students could rely on the provided and constantly available learning materials and the safe, collaborative digital environment to which they could refer.

B. *Technological Challenges and Solutions*

Despite the scarce availability of required technologies for more effective and efficient hybrid learning, the students from an unsafe region (Ukraine) together with their teacher found the following solutions:

- A laptop "one for two"- students connected to the hybrid classroom using one laptop;
- A gadget as an additional asset- a personal cell phone or a digital planchet was used to use a camera or access a collaborative online space.

At the same time, students who were present in class (in Germany) used their individual laptops, being in the classroom in their presence. In such a way, they could experience both synchronous written communication with their peers from Ukraine, teachers, and guest speakers, but also be present onsite and communicate with each other and their teacher, who was present in the classroom.

According to a recent study, "emotional intelligence of students, their psychological condition, and social performance are highly vulnerable" [13]. The communicative gap was widening during discussed HFL classes and the teachers found solutions in adding more interactions, offering synchronous activities and movement. Teachers from both Germany and Ukraine found a great need for *a height-adjustable, movable, and regulated small table* to interact with students more proactively and give instant feedback.

The target group of students experienced communicative difficulties even deeper, as one part of the students came

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from an unsafe region, and for their peers from Germany, this experience of taking a hybrid class was also quite new, eye-opening, and unusual.

C. Anthropocentric Challenges and Solutions

To build communicative bridges and bridge the gap, teachers tied both live and online learners together through the following communicative bonds:

- *Topic-to-go*- the students were provided with relevant and innovative topics for the seminars, having received learning materials in advance and providing them in various formats (podcasts, texts for reading, short videos). Moreover, students were able to choose a topic which is more interesting for them before the Session.
- *Collaborating tools*- such collaborating tools as Mentimeter, Wooclap were used for synchronous polls, diagnostics of students' knowledge, and bringing them together;
- *Digital dialogues*- group discussions, individual reflections, and a free choice of an answer option were available for students. For example, for some of them it was easier to comment on a Chat or participate in activities released on a whiteboard.
- *Q&A*- teachers motivated students to communicate with each other and initiated discussions among them. For example, the students offered short videos, related to the topic of the seminar, demonstrated it via screen sharing, and then initiated group discussions.
- *Synergized communities*-finding common points during discussions, as well as communicating during the post-phase (asynchronously on a digital whiteboard), working together on joint presentations or talks for the coming seminars.

D. ACAD and Tech pods

Social design elements, such as small group work, can increase students' sense of presence and belonging. For example, tech pods will be efficient in reducing the vulnerability of students' emotional intelligence, as well as their psychological condition and social performance. If to rephrase a well-known proverb, "The path to hybrid harbors passes through a techpod" (rephrased from *The path to Heaven passes through a teapot*). Following the CHARM Model of Hybrid Classroom [14], the implementation of *tech pods as group workstations* would facilitate students' active participation and enhance their self-performance, thus fostering emergent activities as an intersectional component of the ACAD model. To avoid the feeling of frustration and loss, the students would be able to engage in both physical and virtual collaboration. Having arranged a controlled environment, another benefit is to reduce distractions and continue with focused group work.

According to the hybrid session participants, a supportive and reliable environment is desirable for students to make them feel more secure and feel their emotional well-being. The consistency and continuity of developing students' *emotional intelligence* through facilitating their feelings and emotions via collaborative experiences established through tech pods is another advantage of this "socially constructing" technology.

Social performance released during the collaborative activities also fostered teamwork spirit and communication skills. Having a balance between individual and group work, the students could "tailor" their individual learning scenarios.

Further implementation of ACAD Framework to boost the efficiency of tech pods is offered as a consequential pathway to improving complex and challenging learning situations and designing learning-enhanced solutions. In terms of the enhancement of tech pods workstations to develop students' emotional, psychological, and social needs, with a focus on both "design time" and "learn-time" directions, ACAD frameworks serve as a creative environment to promote learning and collaboration.

Hybrid classes equipped with tech pods are uniquely designed to enhance students' emotional intelligence, psychological condition, and social performance. Following the principles of the ACAD framework, this study aims to provide a structured approach to designing these environments, ensuring they meet the diverse needs of students and promote holistic development.

V. CONCLUSIONS AND PERSPECTIVES

In this paper, we have predetermined possible technological and anthropocentric solutions, which will foster more effective implementation of hybrid classrooms as safe immersive learning spaces to improve both teachers and students' physical and psychological conditions:

- classrooms, which refer to the Toolkit on Accessibility from UNICEF (e.g. spacious, accessible for people, including those, who are on wheelchairs; appropriate light and sound conditions, etc. refer to [15]);
- height-adjustable, "movable", and regulated small table for teacher (e.g. mobile pneumatic rolling desk);
- node classroom seating and mobile tablet armchairs to allow students to move freely in the classroom onsite and join the group work more effectively;
- tech pods for students (e.g. following CHARM-EU Hybrid Classroom Model with multiple microphones and cameras to provide uninterrupted video and sound);
- training for teachers in the HFL Classroom technology implementation and classroom management (e.g., open and friendly classes with flexible modes of learning both online and on-site).

Further research is needed to enhance socio-emotional interactions in HFL environments and to focus on teacher professional development in the field of socio-emotional learning, empathy, and resilience, underlying that specific

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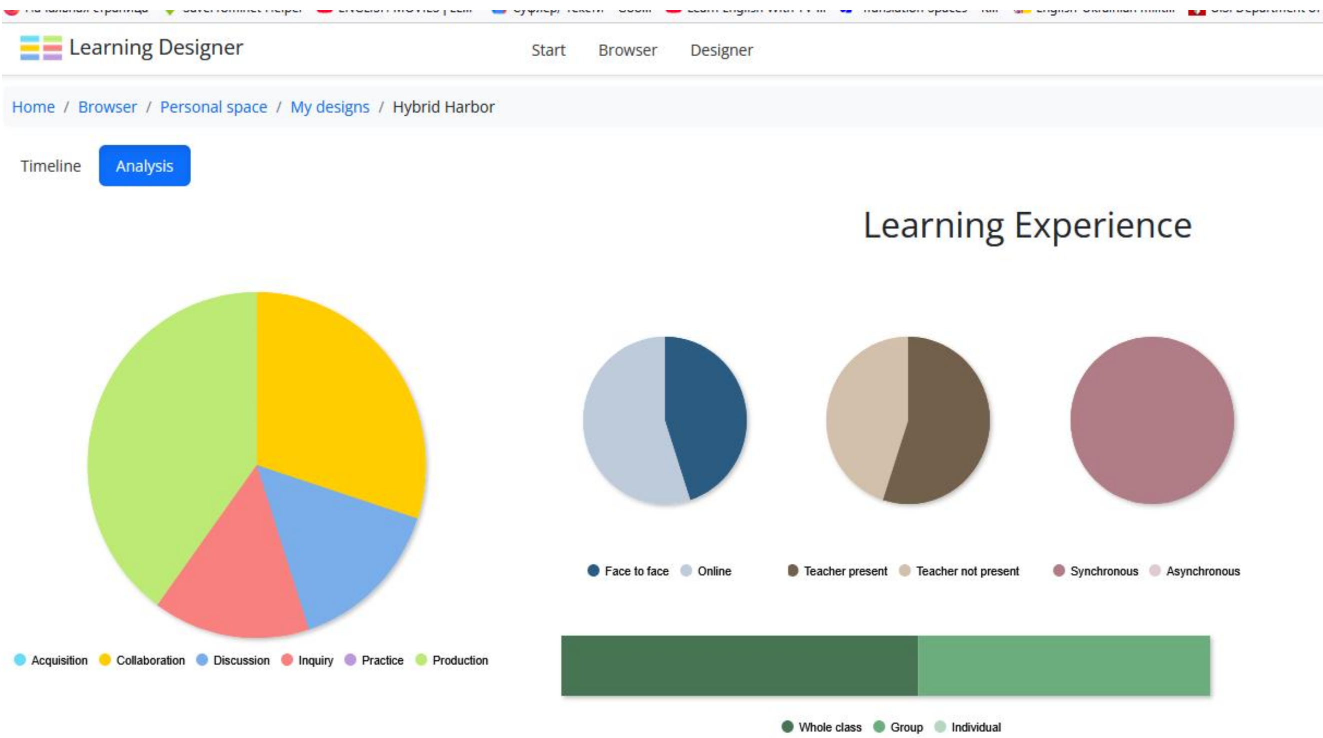

Figure 1. Visual representation of the learning design for hybrid sessions.

skills are needed to teach students from unsafe regions [16] - [18].

Currently, the research is expanding to include more transnational participants, sharing knowledge globally. In 2025, the course "Transcultural project-based learning. Multilingualism through the Arts", will be offered to the German and Ukrainian students in a hybrid format and focus on educational project management, intercultural communication, and interdisciplinarity. The course will involve participation in the eTwinning project BLABL.ART, partnering with institutions from Italy, France, Reunion, and the Czech Republic. Core principles include universality, interdisciplinarity, openness, flexibility, respect, and resilience, which will guide the course's implementation at Julius-Maximilians-Universität Würzburg and other partners.

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Reducing Achievement Gaps: Exploring How Learning by Doing Can Support Diverse Student Success

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***Abstract*— Formative practice applied for a learning-by-doing approach is widely known to be an effective learning method for all students, but for disadvantaged students in particular. Different student populations—ethnic minorities, first generation college students, or economically disadvantaged—have historically had achievement gaps in higher education. Institutions have a responsibility to support diversity, equity, and inclusion, and utilize pedagogical practices and learning technology that can reduce the disparities in student success. This study analyzes a psychology course at the University of Central Florida that assigned formative practice in courseware to determine how this learning-by-doing method impacted exam scores for these student populations.**

Keywords-formative practice; doer effect; diversity; achievement gaps; student success.

I. Introduction

Higher education institutions have an obligation to provide equitable support for all students. As education serves as a powerful tool to address historical and systemic inequities, colleges and universities must enhance support mechanisms for student populations often at greater risk, such as racial or ethnic minorities, first-generation college students, and economically disadvantaged students. The University of Central Florida (UCF), one of the largest public universities in the United States, enrolls significant numbers of students from these groups, making it essential to evaluate how educational technology impacts their learning experiences and work to mitigate disparities in success.

Formative practice—low or no-stakes practice questions—has been found to be effective for all students, but for disadvantaged students most of all [1]. Research suggests that learning by doing could help mitigate disparities in student outcomes [2]. A meta-analysis found that active learning in STEM courses reduced the likelihood of student failure by 1.5 times compared to traditional instruction [3]. Theobald et al. [4] reviewed literature on active learning's impact on Black, Latino, Indigenous, and low-income students, concluding that active learning generally narrows achievement gaps in exam scores and improves passing rates.

Through the ability of digital learning platforms to collect extensive, high-quality micro-level data, we can gain valuable insights into learning processes for formative practice. For instance, data from courseware that integrates formative practice with text content through a learning-by-doing approach have highlighted the learning science principle known as the doer effect. Engaging in practice activities while reading has demonstrated an effect on learning approximately six times greater than reading alone, with studies confirming this relationship as causal [5][6][7]. Further analyses controlling for student characteristics, including minority status, gender, and age, found that the doer effect persists across diverse student groups [5][8].

Courseware with formative practice has been used at UCF in an online Psychology of Sex and Gender course since spring 2020 and prior research had found that assigning the formative practice increased student engagement and exam scores [9]. Given the high proportion of at-risk and disadvantaged students enrolled in the course, a post-hoc analysis was planned to investigate the relationship between learning by doing and learning outcomes for these students. This investigation required collaboration between the university and education technology company in order to combine data sources needed for this study. Notably, the courseware does not collect any student demographic data. Although its predictive models support adaptive activities and instructor dashboards, these models exclude demographic information for both legal and ethical considerations. In this case, the absence of a compelling need to incorporate demographic data guided this approach. There are strong arguments for setting boundaries to protect marginalized groups in machine learning applications, especially when that demographic data may not be necessary or appropriate [10]. Similarly, Baker [11] argues that demographic data in predictive analytics is both controversial and less actionable compared to learning behavior. Research further supports this view, indicating that learning data alone is a strong predictor of student success, outperforming other readiness assessments and demographic variables [12]. Consequently, investigating how this learning-by-doing environment supports specific student groups necessitates collaboration with the university that possesses the relevant demographic information. This investigation is guided by the primary research question: Can assigning learning-by-doing courseware help reduce achievement gaps among at-risk student populations in a psychology course at UCF?

In Section II, the technology, course context and implementation strategies, and data preparation are all described. In Section III, results are presented first using exploratory data analysis—including descriptive statistics and data visualizations—and second using the doer effect analysis and regression models to determine the significance of doing formative practice and student characteristics on exam scores. Section IV discusses limitations, conclusions, and future work.

II. METHODS

The courseware was generated using artificial intelligence and the volume of formative practice required for effective learning-by-doing from textbook materials [13]. These AI-generated questions underwent rigorous evaluation using student data, including data from UCF courses. Findings reveal that AI-generated questions perform comparably to human-authored ones, with students perceiving no significant differences, thereby validating their effectiveness in learning-by-doing environments [13].

This courseware served as the primary learning material and the instructor assigned the formative practice activities as completion-based homework. All sections of the course were synchronous online, mitigating some impacts from COVID-19 regarding modality during that time. In spring 2020 (S20), the assignment was worth 2% of the students' grade, whereas in spring 2021 (S21) and spring 2022 (S22) it was worth 20% of the grade. Prior research found these implementation changes resulted in increased student engagement and improved exam scores [9].

To assess the impact of the learning-by-doing method on various student populations, it was necessary to integrate multiple data sources. The first data source was raw clickstream data from the courseware platform, capturing timestamps for actions such as page visits and question interactions. This information is linked to anonymized numeric student identifiers, ensuring privacy. After obtaining institutional review board approval for this post-hoc analysis, these numeric identifiers were provided to UCF where grade data and student characteristics were added to a spreadsheet. Using the numeric identifiers allowed the VitalSource team to combine the student characteristics with the data set of millions of clickstream events for anonymous analysis.

While there were a combined 388 students across semesters at the start of the course, 81 students were removed for not completing the course (Grade = "W", "WD", "S" or "U")—a percentage not uncommon given the enrollment process prior to the add/drop date, and the community service hours required as a designated service-learning course. An additional 19 students were removed for not taking all 3 exams (18 were female, 12 were Hispanic). There were 287 students remaining in the data set for analysis: 90% female and 10% male; 50% white, 31% Hispanic/Latino, 10% Black/African American, 3% mixed race; 78% full time and 22% part time; 80% non-first generation and 20% first generation college students; 55% non-Pell eligible and 45% Pell eligible (Pell eligible being a proxy for economically disadvantaged). Note that as a post hoc analysis of natural learning contexts, student characteristics are a reflection of the course population and are not balanced, especially gender in this instance.

III. RESULTS

A. Engagement

The first step of investigating the data is to gain insight into how students engaged with the courseware, often related to course policies and implementation strategies. In Figure 1, each semester is shown as a graphic visualization where the number of students are on the y-axis and each page of the course is represented linearly on the x-axis. In this way, time is also approximated on the x-axis, as students move chronologically through the courseware over the course of the semester. For each page of the courseware (a vertical slice of the graph), the blue dot represents the number of students who did the reading, the red dot is the number of students who did the formative practice, and the green dot is the quiz. In the S20 graph, there is a vertical gap between the reading and doing dots, indicating some students were reading without doing. This reading-doing gap is fairly typical. However, in S21 and S22, the reading-doing gap is nonexistent. These semesters also show less attrition within units and across the course. The change in incentive for doing the formative practice had a large impact on student engagement patterns.

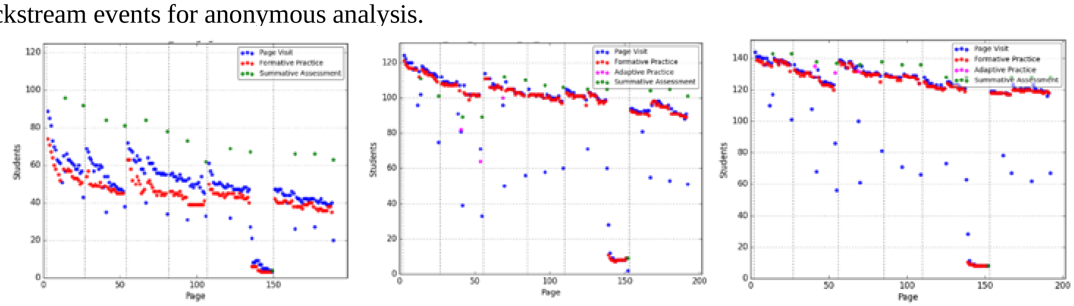

Figure 1. Engagement graphs for S20, S21, and S22 (left to right).

TABLE I. FORMATIVE PRACTICE COMPLETION BY SEMESTER

Semester	Students	Mean	STD	MIN	25%	50%	75%	MAX
Spring 2020	62	395.90	283.74	0.0	52.25	582.0	652.0	707.0
Spring 2021	99	610.43	149.95	0.0	618.50	665.0	672.5	888.0
Spring 2022	126	627.77	123.33	0.0	658.25	667.0	670.0	727.0

B. *Exam Scores*

The largest graded component of this course was the exam, which provides a quantitative measure of comparison across semesters and between demographic groups. Table II shows combined exam scores for each semester. As would be hoped from the increase in student engagement with the formative practice, exam scores increase across the 25th, 50th, and 75th percentiles. S22 has a very low scoring minimum outlier which does impact the overall mean, but the trend is as expected.

Viewing exam scores by gender (Table III), a few trends emerge, though the smaller proportion of males compared to females is important to keep in mind. For both S20 and S21, males had higher exam scores at the 25th and 50th percentile, but not the 75th percentile. For S22, females had higher scores for the 25th, 50th, and 75th percentile.

Viewing exam scores by ethnicity (Table IV) shows trends across semesters as well. With a few exceptions (S20 25th and S21 50th), white students had the highest exam scores across percentiles. Despite having the second highest population represented, Hispanic/Latino students typically had the lowest scores, with the exception of S22, where they surpassed the Black/African American group at the 25th and 50th percentile.

Table V reviews exam scores by Pell eligibility status, often used as a proxy for economic status. Students who were not Pell eligible outperformed those who were across each percentile and semester. These groups were most closely aligned in performance in S21, also where the proportion of students who were and were not eligible were nearly equal. Table VI shows students who were full time outperformed those who were part time across all percentiles and semesters (except S21 25th). Table VII shows that students who were first generation college students performed worse than their peers across all semesters.

Examining these exam scores by different student groups clearly shows the achievement gap reported in research. However, further analysis will determine if these differences are significant.

TABLE II. STUDENT EXAM SCORES BY SEMESTER

	Students	Mean	STD	MIN	25%	50%	75%	MAX
Spring 2020	62	450.23	68.88	282.0	405.00	466.5	494.25	594.0
Spring 2021	99	469.14	69.67	307.0	410.50	472.0	527.50	595.0
Spring 2022	126	467.66	78.78	183.0	420.75	477.0	528.00	609.0

TABLE III. EXAM SCORES BY GENDER FOR ALL SEMESTERS

Semester	Gender	Students	Mean	STD	MIN	25%	50%	75%	MAX
Spring 2020	Female	59	448.83	70.30	282.0	399.00	462.0	495.00	594.0
	Male	3	477.67	14.43	461.0	473.50	486.0	486.00	486.0
Spring 2021	Female	86	468.67	71.68	307.0	409.75	466.0	533.50	595.0
	Male	13	472.23	56.87	370.0	451.00	478.0	511.00	547.0
Spring 2022	Female	112	468.69	79.51	183.0	425.25	477.0	531.00	609.0
	Male	14	459.43	74.90	348.0	397.50	464.0	518.25	573.0

TABLE IV. EXAM SCORES BY RACE FOR ALL SEMESTERS

Semester	Ethnicity	N	Mean	STD	MIN	25%	50%	75%	MAX
Spring 2020	White	31	464.32	71.59	282.0	417.00	486.0	505.50	594.0
	Hispanic/Latino	21	426.95	63.50	315.0	372.00	426.0	486.00	501.0
	Black/African American	7	454.29	70.40	330.0	433.50	450.0	487.50	558.0
Spring 2021	White	47	473.70	70.65	340.0	424.00	466.0	538.00	595.0
	Hispanic/Latino	34	456.56	73.77	307.0	406.00	457.0	525.25	595.0
	Black/African American	11	475.55	61.36	388.0	418.00	496.0	532.00	547.0
Spring 2022	White	66	478.56	72.69	309.0	438.75	484.5	531.00	609.0
	Hispanic/Latino	35	457.23	77.74	255.0	397.50	466.0	513.00	590.0
	Black/African American	12	429.50	112.23	183.0	371.25	442.5	518.25	552.0

TABLE V. EXAM SCORES BY PELL ELIGIBLE FOR ALL SEMESTERS

Semester	Pell	Students	Mean	STD	MIN	25%	50%	75%	MAX
Spring 2020	Yes	36	434.83	76.46	282.0	381.00	444.0	486.00	594.0
	No	26	471.54	50.76	360.0	432.75	481.5	502.50	561.0
Spring 2021	Yes	48	466.90	74.65	307.0	409.00	469.0	537.25	595.0
	No	51	471.25	65.32	343.0	424.00	472.0	524.50	595.0
Spring 2022	Yes	44	437.86	86.83	183.0	384.00	448.5	498.75	590.0
	No	82	483.65	69.52	309.0	450.00	493.5	533.75	609.0

TABLE VI. EXAM SCORES BY FULL TIME/PART TIME FOR ALL SEMESTERS

Semester	Course Load	Students	Mean	STD	MIN	25%	50%	75%	MAX
Spring 2020	Full Time	43	462.42	60.61	324.0	423.0	480.0	496.50	561.0
	Part Time	19	422.63	79.68	282.0	360.0	432.0	484.50	594.0
Spring 2021	Full Time	79	472.71	72.46	307.0	409.0	478.0	532.00	595.0
	Part Time	20	455.05	56.76	340.0	418.0	436.0	498.25	547.0
Spring 2022	Full Time	101	472.96	79.17	183.0	429.0	477.0	534.00	609.0
	Part Time	25	446.24	74.89	309.0	396.0	455.0	492.00	579.0

TABLE VII. EXAM SCORES BY FIRST GENERATION FOR ALL SEMESTERS

Semester	First Gen	Students	Mean	STD	MIN	25%	50%	75%	MAX
Spring 2020	Yes	15	435.80	65.75	324.0	390.00	444.0	483.00	558.0
	No	47	454.83	69.90	282.0	415.50	477.0	496.50	594.0
Spring 2021	Yes	21	460.71	78.10	307.0	403.00	463.0	523.00	571.0
	No	78	471.41	67.60	340.0	421.75	473.5	528.25	595.0
Spring 2022	Yes	22	436.86	82.23	300.0	362.25	439.5	490.50	585.0
	No	104	474.17	76.86	183.0	435.75	484.5	531.00	609.0

Figure 2 shows a visualization of students' total reading (x-axis) by total exam score (y-axis) for all three semesters. The scatterplot has a general triangular shape, nicknamed a data-tornado by the authors. A line fit to this data would likely have a slightly positive slope. No discernable difference in pattern is observed between semesters.

By contrast, Figure 3 shows a data wall; total exam scores and total doing has produced a nearly vertical plot. The formative practice was assigned and nearly all students did nearly all the practice, therefore, most dots are along the x-axis point for maximum assigned practice. Since the vertical line has a wide range of exam scores, does that mean the practice did not help improve scores? That is not possible to tell from this plot. If doing practice increased exam scores by 5%, we would still see the same range in scores. Interestingly, there are some dots to the right of the main line; those students did extra questions in the chapter that was not assigned and therefore have a higher practice total than their peers. Some students are to the left of the data wall, showing not all students did all practice. Notably, there are far more blue dots from the S20 semester to the left, which aligns with lower formative engagement.

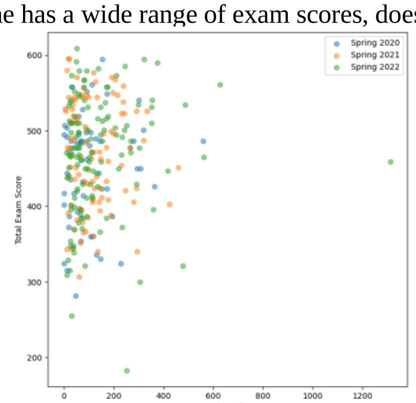

Figure 2. The data tornado: total reading by exam score.

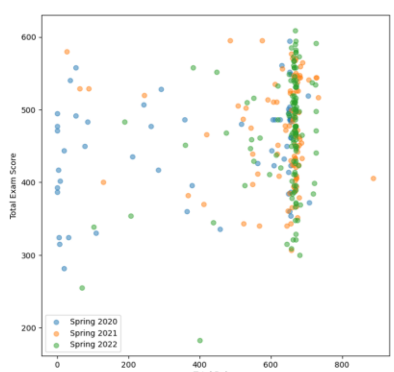

Figure 3. The data wall: total doing by exam score.

C. The Doer Effect

The doer effect analysis that is the foundational learning science principle supporting this learning by doing method requires data for reading, doing, and summative assessments—all of which we have for these courses. If we combined data from all semesters, we could find the same doer effect results; however, that is a misleading finding. Variation for within-student doing is necessary to determine the effects of doing practice on exam scores. There is variation in doing for S20, but very little variation in S21 or S22. In fact, the data wall is so vertical for S21 and S22, that the few outliers skew S21 positive and S22 negative in such a way that they cancel each other out, resulting in the misleading combined doer effect result. It is not possible to do a doer effect analysis for S21 and S22, but it is possible for S20 alone. In Table VIII, we see that the doing coefficient is significant, but the reading coefficient is not. The doer effect ratio (doing over reading coefficient) would be about 3, however, because reading is not statistically significant, the ratio is reported as infinity. This result is consistent with results reported by [6][7]. It is also likely that if the course had been closer to 100 students, reading would have become significant.

TABLE VIII. DOER EFFECT SPRING 2020

R1 (84)	Estimate Std.	Error	t Value	Pr(<|t|)
Intercept	461.196	10.238	45.047	<2e-16 ***
Total Reading	4.745	10.923	0.434	0.666
Total Doing	12.619	6.162	2.048	0.045 *

D. Regression Models

To determine how reading, doing practice, and student characteristics impacted exam scores, they were used as covariates in a linear regression model. In a linear regression for all semesters combined with all demographic covariates plus reading and doing (Table IX), the following covariates are significant: Hispanic/Latino, Pell eligible, full time/part time, and total doing. The linear regression for only S20 has the significant covariates of Hispanic/Latino, full time/part time, and total doing (Table X). This is similar to the results for all semesters combined. This semester produced the largest variation in doing practice so it is expected that doing would be significant to exam scores, as students who did more practice performed better than their peers.

TABLE IX. ALL SEMESTERS COMBINED

	Estimate Std.	Error	t Value	Pr(<|t|)
Intercept	509.092	20.048	25.394	<2e-16 ***
Male	5.745	14.492	0.396	0.692
American Indian/ Alaska Native	13.148	73.598	0.179	0.858
Asian	7.802	29.921	0.261	0.795
Black/African American	-11.531	15.088	-0.764	0.445
Hispanic/Latino	-22.072	10.143	-2.176	0.030 *
International	-14.078	36.406	-0.387	0.699
Multi-racial	0.355	24.760	0.014	0.989
Race Not Specified	5.890	71.622	0.082	0.935
Pell Eligible	-21.093	9.310	-2.266	0.024 *
First Generation	-6.812	11.421	-0.597	0.551
Age	-0.955	0.855	-1.118	0.265
Part Time	-22.155	10.928	-2.027	0.044 *
Total Reading	4.897	4.439	1.103	0.271
Total Doing	10.500	4.484	2.342	0.020 *

TABLE X. SPRING 2020

	Estimate Std.	Error	t Value	Pr(<|t|)
Intercept	463.784	38.068	12.183	<2e-16 ***
Male	61.713	42.155	1.464	0.150
Black/African American	1.490	28.579	0.052	0.959
Hispanic/Latino	-43.901	20.979	-2.093	0.042 *
Multi-racial	-6.142	67.090	-0.092	0.927
Pell Eligible	-23.869	18.131	-1.316	0.194
First Generation	-0.051	21.620	-0.002	0.998
Age	1.615	1.449	1.115	0.270
Part Time	-42.747	19.820	-2.157	0.036 *
Total Reading	5.282	10.847	0.487	0.629
Total Doing	14.026	6.586	2.130	0.038 *

In spring 2021, the results of the regression model in Table XI show there are no significant covariates. The lack of significance is overall positive, as the differences between demographic groups did not produce significant differences in exam scores. But does the lack of significance for doing mean it was not important for exam scores? No. If we recall the data wall, nearly all students did nearly all practice, and therefore there was not enough variation in doing to be statistically significant. In the context of implementation practices causing very high engagement, no significance indicates a successful engagement strategy.

TABLE XI. SPRING 2021

	Estimate Std.	Error	t Value	Pr(<|t|)
Intercept	529.536	51.570	10.268	<2e-16 ***
Male	9.838	22.975	0.428	0.670
American Indian/ Alaska Native	9.261	78.572	0.118	0.906
Black/African American	11.767	25.671	0.458	0.648
Hispanic/Latino	-17.474	17.032	-1.026	0.308
Multi-racial	20.231	32.025	0.632	0.529
Pell Eligible	2.309	15.737	0.147	0.884
First Generation	-11.475	19.242	-0.596	0.553
Age	-2.422	2.397	-1.010	0.315
Part Time	-12.214	20.458	-0.597	0.552
Total Reading	2.659	11.450	0.232	0.817
Total Doing	-10.011	11.010	-0.909	0.366

In spring 2022, the regression model in Table XII shows significant covariates of Pell eligible, total doing, and marginal significance for Black/African American. The exam scores had a wider distribution for S22 than for S21, so finding significant covariates is not unexpected. The doing covariate being significant again is indicative of a wider variation of doing for some students that did correlate to exam scores. The S22 semester did have some extreme outliers for exam scores that could also be contributing to the significance results.

TABLE XII. SPRING 2022

	Estimate Std.	Error	t Value	Pr(<|t|)
Intercept	522.164	29.993	17.410	<2e-16 ***
Male	9.799	22.230	0.441	0.660
Asian	3.995	31.990	0.125	0.901
Black/African American	-41.823	24.853	-1.683	0.095 .
Hispanic/Latino	-19.644	16.390	-1.199	0.233
International	-10.596	38.534	-0.275	0.784
Multi-racial	-32.696	54.366	-0.601	0.549
Race Not Specified	-0.526	74.509	-0.007	0.994
Pell Eligible	-34.953	15.779	-2.215	0.029 *
First Generation	-5.977	19.465	-0.307	0.759
Age	-1.723	1.236	-1.394	0.166
Part Time	-11.009	18.027	-0.611	0.543
Total Reading	8.164	5.715	1.429	0.156
Total Doing	29.253	11.951	2.448	0.016 *

IV. CONCLUSION AND FUTURE WORK

This study set out to explore whether learning-by-doing courseware can help reduce achievement gaps for at-risk student populations in a psychology course at the University of Central Florida. At its core, the research is motivated by the imperative for higher education institutions to provide equitable support mechanisms for all students, particularly those who have historically faced systemic barriers to academic success. By leveraging the rich behavioral data from formative practice embedded in digital courseware

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combined with exam scores and demographic data—we aimed to understand how such tools can contribute to a more inclusive and effective learning environment. The significance of this work lies in its potential to inform scalable, ethical interventions that support academic equity.

These results, while not proving a causal relationship, combine to provide a conclusion that the formative practice assigned in the courseware benefited all students. The variation in engagement for S20 gave a unique opportunity to do a doer effect regression analysis that gave correlational results in line with prior doer effect findings [6][7]. In all cases where a correlational doer was found (even in cases of infinity due to the reading covariate not being significant), a causal doer effect analysis was also confirmed [7], providing reasonable argument to expect the same would be found here if the conditions allowed for the causal analysis.

The relationship between the course policy of assigning practice, increased student engagement, and the impact on demographic disparities on exam scores is also supported by these results. By increasing the percentage of the students' grade for doing the formative practice, in S21 student engagement increased to the point that doing no longer became significant in the linear regression model for exam scores. No other demographic characteristics were significant—a positive finding.

There are limitations to this analysis. Because the sample size in S20 was only 62 students, inclusion of several demographic categories limited statistical power. We acknowledge that a larger number of independent variables may overfit the data, but we included these variables to explore potential achievement gap trends. Comparing different cohorts of students always brings variation that cannot be controlled for. The differences between the S21 and S22 results could easily be the result of the constitution of those students' characteristics. Future research could study results excluding extreme outliers to investigate the impact of those students on overall results. Future research should also examine more semesters to better identify trends over time, including semesters prior to S20 where there was no formative practice available to provide a different control measure for comparison.

The demographic data reveals that there is an achievement gap for student populations related to race, first generation status, and economic status. As education is an essential component for student success later in life, supporting student success with a focus on reducing or eliminating the achievement gap for these groups continues to be a vital mission in higher education. Any learning tool and pedagogical strategy that can work towards mitigating these achievement gaps should be embraced.

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Using Zoom Avatars to Weaken Zoom Fatigue in Tertiary Education

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***Abstract* — As a result of the Corona pandemic, universities and other educational institutions were forced to switch completely to online teaching and distance learning, primarily using video conferencing systems such as Zoom, Microsoft Teams and Google Meet. Due to the lack of personal participation and the limitations of video conferencing technology, students experienced Fatigue and an increasingly declining motivation and ability to concentrate. The term "Zoom Fatigue" has become established for this phenomenon and has already been addressed in numerous studies at universities, dealing with several Fatigue symptoms in online classes. This study examines the extent to which at least some of the factors that cause Zoom Fatigue could be avoided or mitigated by using Avatar-based virtual learning environments in higher education. As part of a module in the master's program "Integrated Innovation Management" at the University of Applied Sciences in Würzburg, various desktop-based teaching environments were used (face-to-face, Zoom with camera, Zoom with Avatar) and then evaluated via a survey. When using the Zoom Avatars, some of the known Zoom Fatigue causes were specifically avoided. As predicted, the results show that the usage of Zoom Avatar environment has significantly lower perceived Fatigue than Zoom camera environment. Surprisingly, the value for General exhaustion was highest for the face-to-face program, what we call 'self-motivated Fatigue' because face-to-face is clearly preferred by the students. Further analyses on the use of virtual environments with higher immersion (gather.town, framevr.io) are planned.**

Keywords - Virtual Learning Environments; Online Teaching; Tertiary Education; 2D and 3D Avatar-Based Desktop-Environments; Desktop virtual reality; Zoom Fatigue.

I. INTRODUCTION

The use of online courses and distance learning was the result of the corona pandemic, especially in the years 2020 to 2022 [1] with the primary use of classic video conferencing tools [2], [3]. Besides the advantage that lectures and courses could be given instead of cancelling, the longtime usage of this Video Conferencing tools caused specific symptoms of exhaustion among the participants [4], [5]. These symptoms of exhaustion, like declining motivation, decreasing ability to concentrate, and even headaches and visual disturbances, become established under the term "Zoom Fatigue" [6]-[8]. Even after the lockdowns and the Corona measures were lifted, online meetings and courses were and continue to be used on an increased scale, primarily using video conferencing systems [9], [10]. Therefore, it can be assumed that the effects of Zoom Fatigue are effective to an increased extent and affect students to a considerable extent. The present study examines the extent to which at least some of these factors, like the discomfort of always seeing yourself as a camera image or the feeling of always being watched by others, could be avoided or mitigated using Avatar-based virtual learning environments in higher education. So far, several studies have established both the basic suitability and various advantages of such worlds [11]-[14], but so far, there has been no specific investigation into the extent to which Avatar-based environments have the potential to reduce Zoom Fatigue.

To get a realistic picture, the challenge was to analyze not only one or two sessions but at best, a complete lecture or module within tertiary education. Ideally, the students should be the same, and the software should be accessible to all and run on their own computers. To solve these difficulties, a whole lecture with the same students from one semester was used and by using the known and familiar Zoom software, there were no technical issues. The idea of the research design is to regularly change the teaching environment. Therefore, two courses were always held in each environment and then directly assessed by the students. This was intended to answer the research question of whether different environments change perceptions of Fatigue and whether Avatars can improve these perceptions. The purpose of this study, including the research before, is to analyze alternatives for classical video conferencing systems to find recommendations for future online courses at universities [12]-[14]. The limitation is the small number of participants because we are dealing with an exploratory case study and, therefore, the results cannot be Generalized at all.

Within Section I, a short overview of Zoom Fatigue causes is given in subchapter A. and Zoom Fatigue symptoms in subchapter B. within the Introduction. Section II takes a look at related work. Section III describes the differently used learning environments, Classroom teaching in subchapter A, Zoom with video in subchapter B., and Zoom with Avatars in subchapter C. Subchapter D. and E. explain the measuring instrument, experimental procedure, and the sample. The first results can be shown in Section IV and then discussed in Section V. The paper ends in Section VI with conclusions and future work within this research area.

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A. Zoom Fatigue Causes

The causes of this Fatigue are manifold and range from poor image and sound quality to information overload and a disturbing feeling due to the constant mirror image of the video camera [15]-[17]. Many people who use virtual meetings from Zoom, Skype, Teams, or other providers find virtual conferences more stressful and tiring than real meetings [15]. There may be various reasons for this, which can be seen in Figure 1 [15].

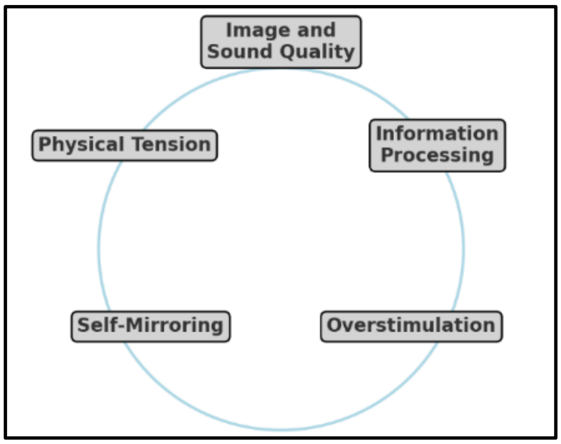

Figure 1. Zoom Fatigue Causes.

The fact that participants see themselves reflected in the video is one of the causes of Zoom Fatigue. This can subconsciously trigger stress, which is also caused by physical tension [17]. A non-verbal behavior of these relationships is expressed by the fact that people who are strangers usually keep a certain distance from each other and avert their eyes as soon as they meet in a confined space [18]. This non-verbal behavior changes on virtual video platforms, as eye contact is inevitable. The speaker view, in which one of the people appears larger on the screen and the others in smaller tiles above, increases this discomfort, as the personal distance to other people is perceived as too close [15], [19].

B. Zoom Fatigue Symptoms

The symptoms of Zoom Fatigue can manifest themselves on both a psychological and physical level [20]. The Universities of Stanford and Gothenburg and the Institute of Occupational Medicine have investigated the topic and have concluded that a variety of impairments can occur. These are listed in more detail in Table 1 [21].

TABLE I. ZOOM FATIGUE SYMPTOMS

Psychological Symptoms	Physical Symptoms
Reduced concentration	Headache
Restlessness	Back pain
Irritability	Vision problems
Lack of balance	Sleep problems

12% of respondents stated in a corresponding study that Zoom Fatigue was always present, while 83.3% said it was regularly the case [15]. It was found that it was not the number of virtual events that was decisive but above all the respective implementation and design. For female respondents in particular, the researchers concluded that seeing themselves in video meetings led to a greater state of Fatigue [15]. This could be because they were more aware of how others perceived them [22]. The relationship between the real-time transmission of Zoom and the higher awareness of self-evaluation is referred to as the "screen-mirror effect" [8]. The mode of self-viewing in Zoom or other virtual video conferencing systems can act as a trigger that increases social anxiety through negative self-images as participants subconsciously compare their behavior or appearance to ideal standards [8].

II. RELATED WORK

The scientific debate on the topic of Zoom Fatigue has become increasingly important due to the causes and symptoms described above. Various studies are already dedicated to analyzing its cause, effects, and possible countermeasures, particularly in the university and college environment. A study from 2022 analyzed how video conferencing Fatigue is associated with symptoms of burnout and depression. The results indicate that people with a tendency towards emotional instability and negative emotions are at increased risk of burnout and depression symptoms due to frequent video conferencing. The authors emphasize that the frequent feeling of being overwhelmed by video conferencing causes not only physical but also mental exhaustion [23]. Another study found that Zoom Fatigue is particularly prevalent among students and teachers who must complete many digital events over a longer period. The qualitative analysis showed that the subjective perception of Fatigue is often exacerbated by technical problems, lack of social interaction, and the duration of the sessions [22]. A study of medical students who regularly used video conferencing systems during the Covid-19 pandemic found that a significant proportion of students suffered from symptoms of Fatigue [24]. The findings highlight the need to develop strategies to minimize the negative impact of online learning environments on students' well-being. The study often focuses on short-term objectives and not long-time online lectures for a whole semester [11]. Therefore, this study analyses a regular course over an entire semester with changing teaching and learning environments to get a realistic picture of perceived Fatigue for students.

III. METHOD

In the following, we present the different environments which were used for the first results of this study. These are the classroom environment for face-to-face teaching (subchapter A.), Zoom with camera tiles (subchapter B.), and Zoom with Avatars (subchapter C.). Subchapter D. contains the Measuring instruments, subchapter E. describes the experimental procedure and subchapter F. explains the Sample.

A. Classroom Environment for face-to-face teaching

The face-to-face teaching was given in some bigger seminar rooms for front-end lectures alternated with group work in smaller rooms for 5 to 6 people. All rooms have natural light with big windows and flexible furniture. Figure 2 gives an impression of the seminar room style.

Figure 2. Seminar rooms for front end in the upper part and group work in the lower part of the picture.

B. Zoom with video tiles

Zoom is one of the Classic Video Conferencing Tools with quite widespread usage for education, especially during the COVID-19 pandemic [9]. Zoom allows for one or more people to interact through video-based visual and audio communication, and chat communication [25]. It is also possible to create subgroups (Break-out rooms) for group work or group discussions. There is also the possibility to share the screen with other participants, to do little surveys, and to use a whiteboard. The classic appearance is the monitor full of video tiles with the participants of the Zoom meeting, as shown in Figure 3.

Figure 3. Video tiles on monitor for classical zoom video lecture.

C. Zoom with Avatars

Besides the classic use of video tiles to enable visual interaction during meetings or lectures, Zoom also offers the option to represent participants through Avatars. These Avatars can be customized, ranging from simple animal representations to advanced humanoid figures that reflect users' facial expressions—and in some cases, their gestures—in real time. Customization options include not only skin tone, hairstyle, and clothing, but also detailed facial features [26]. Importantly, Zoom Avatars are not static: they display facial expressions and certain movements while speaking. For example, gestures such as a wide-open mouth, laughter, head shaking, or nodding are automatically mirrored by the Avatar. This creates a dynamic rather than static appearance, which is relevant for interpreting the results of this study. In this context, only humanoid Avatars were used to maintain the professional character of the lecture, although Zoom also offers playful options such as animal or fantasy Avatars. Figure 4 illustrates the appearance of the Zoom Avatar function as used in this study.

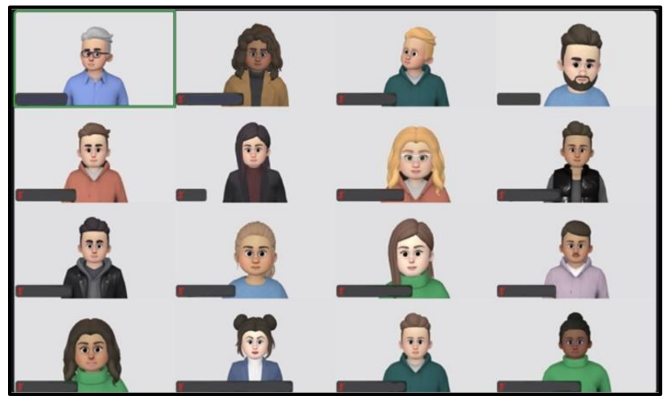

Figure 4. Zoom monitor screen with Avatar tiles.

D. Measuring Instrument

The questionnaire that was used includes several parts to measure topics for Zoom Fatigue, learning motivation, communication, and General issues. In this paper, only the Zoom Fatigue questions are presented, because the initial results are focused on that. Future publications will include the other measurement instruments also. The Stanford Virtual Human Interaction Lab developed a scale (ZEF scale) that aims to systematically assess the specific stress and Fatigue symptoms that arise from the intensive use of video conferencing [27]. The ZEF scale is divided into 5 "Constructs" and 3 questions each. Based on this scale, 5 questions were selected, one from each "Construct", to obtain a comprehensive impression but, at the same time, to limit the scope of the questions. To include also Zoom Fatigue causes four questions were added. The first asks about the lack of opportunities for informal communication and the second about stimulating and inspiring aspects of the environment [20]. The third question is about the discomfort of constantly seeing one's own image in the video tile, and the fourth addresses the feeling of being watched by others. All items were measured using a 5-point Likert scale. The whole questionnaire is shown in Table II.

E. Experimental procedure

The study was done within the lecture "trend analysis and innovation assessment" (Trend) of the master study program "Integrated Innovation Management" at the Technical University of Applied Sciences Würzburg-Schweinfurt Germany. The lecture was given in the winter semester from October 2024 until December 2024, for 6 days. The seminar duration was always from 9:00 a.m. to 1:15 p.m. The first two lecture dates were given in the classroom as face-to-face teaching. The following two lecture dates were given online with Zoom using the classical video tiles configuration. For the last two lecture dates, it was switched to the Zoom Avatar style. The three measurement time points were always conducted immediately after the end of each of the three different sections of learning environments via an online questionnaire. The questions were given in German language.

TABLE II. QUESTIONNAIRE FOR ZOOM FATIGUE SYMPTOMS AND CAUSES

Zoom fatigue symptoms			
Item/Question	1	General fatigue	I felt exhausted after a lecture
Item/Question	2	Visual fatigue	I had visual problems after a lecture
Item/Question	3	Social fatigue	After a lecture, I avoided social situations
Item/Question	4	Motivational fatigue	After a lecture, I felt like doing nothing
Item/Question	5	Emotional fatigue	I felt emotionally drained after a lecture
Zoom fatigue causes			
Item/Question	6	Networking Opportunities	In the virtual environment, I had opportunities for informal exchange and networking.
Item/Question	7	Stimulating environment	I found the virtual environment stimulating and inspiring.
Item/Question	8	Self-mirroring	I found it uncomfortable to constantly see myself on the screen.
Item/Question	9	Feeling observed	I feel uncomfortable thinking that others are observing my video image.

F. *Sample*

A total of 17-20 subjects participated in the three measurement time points (average of 18.33). The average age of the subjects is 24.85 years, with a minimum of 22 years and a maximum of 30 years. The gender distribution was 8-9 males and 9-11 females.

IV. RESULTS

The results section is divided into different chapters. First, there is an analysis of the descriptive statistical data in subchapter A. Subchapter B. contains several variance analyses to see if there are significant differences between the three different learning environments in terms of Zoom Fatigue items based on the ZEF scale. To analyze possible relationships between the symptoms and causes of Zoom Fatigue, the results of a regression analysis are presented in subchapter C.

A. *Analysis of Descriptive Statistic*

As described in Section III, three different learning environments were used in the lecture Trend, face-to-face teaching, Zoom with camera, and Zoom with Avatars. All environments were used within two lecture dates each from 09:00 a.m. - 1:15 p.m. Generally, the level of Fatigue is not quite high regarding the maximum scale of 5. Only two items get above 3.5, as shown in Table III. These are the General Fatigue at face-to-face teaching with 3.60 and General Fatigue with Zoom camera with 3.53. All the other Fatigue items are between 1.76 for Visual Fatigue with face-to-face teaching and 2.72 for General Fatigue with Zoom Avatar. Looking at the average values for each Fatigue item above the three different environments, the range is between 3.29 for General Fatigue and 2.00 for Visual Fatigue. Overall, it can be said that only a moderate level of exhaustion could be measured with almost always under 3.00 except for the General Fatigue.

TABLE III. DESCRIPTIVE ANALYSIS ZOOM FATIGUE SYMPTOMS

Learning environment	N	Mean	Standard Deviation	Minimum	Maximum
General fatigue					
face-to-face teaching	20	3.60	0.883	2	5
Zoom Camera	17	3.53	0.874	1	4
Zoom Avatar	18	2.72	0.752	1	4
Total	55	3.29	0.916	1	5
Visual fatigue					
face-to-face teaching	17	1.76	0.903	1	4
Zoom Camera	17	2.24	1.033	1	4
Zoom Avatar	18	2.00	0.767	1	3
Total	52	2.00	0.907	1	4
Social fatigue					
face-to-face teaching	20	2.00	1.026	1	5
Zoom Camera	16	2.31	1.138	1	4
Zoom Avatar	18	1.94	0.802	1	3
Total	54	2.07	0.988	1	5
Motivational fatigue					
face-to-face teaching	19	2.37	1.065	1	5
Zoom Camera	17	2.41	1.121	1	4
Zoom Avatar	18	2.17	0.786	1	4
Total	54	2.31	0.987	1	5
Emotional fatigue					
face-to-face teaching	20	2.60	1.142	1	5
Zoom Camera	16	2.69	1.014	1	4
Zoom Avatar	18	2.11	0.963	1	4
Total	54	2.46	1.059	1	5

B. *Analysis of Variance for Significant Differences*

In the next section, the 5 items on the Zoom Fatigue symptoms are tested for differences between the mean values of the three surveys using a single-factor analysis of variance (ANOVA). As the number of test subjects was less than 30, the rank variance analysis according to Kruskal & Wallis (H-test) was also calculated in addition to the single-factor analysis of variance. In the single-factor analysis of variance, only the assessment of General exhaustion was found to be significant ($p = 0.004$). The effect size η^2 is 0.14 and can, therefore, be categorized as large, as shown in Table IV.

TABLE IV. UNIVARIATE ANALYSIS OF VARIANCE

General Fatigue	Sum of squares	df	Mean of the squares	F	p =	η^2 =
Between groups	8.699	2	4.35	6.172	0.004	0.192
Within groups	36.646	52	0.705			
Total	45.345	54				
$\eta^2 > 0.14$ = large power						

The result of the ANOVA is confirmed by the H-test from Kruskal & Wallis [28]. Here too, only the omnibus test for General exhaustion is significant at $p = 0.002$. Therefore, both tests concluded that there are significant differences between the three groups overall. The subsequent post-hoc test shows, both in the ANOVA and the H-test, that the group using Zoom Avatars differs significantly from the other two learning environments.

The p-value is in the significant range between 0.006 and 0.017 for the comparisons with this environment, as can be seen in Table V. The effect size is also large in each case, which means that it can now be said with certainty that the results of the Zoom Avatar learning environment differ significantly from the other two.

TABLE V. H-TEST KRUSKAL & WALLIS

General Fatigue							
Post Hoc Tests: Anova Group combinations	N 1	N 2	Mean 1	Mean 2	Mean difference	p =	Power d =
face-face-teaching (1) & Zoom Camera (2)	20	17	3.60	3.53	-0.07	0.965	0.080
face-face-teaching (1) & Zoom Avatar (3)	20	18	3.60	2.72	-0.88	0.006	1.066
Zoom Camera (2) & Zoom Avatar (3)	17	18	3.53	2.72	-0.81	0.017	0.992
d > 0.8 = large power							
General Fatigue							
Post Hoc: Kruskal & Wallis H-Test Group combinations	N 1	N 2	Average rank 1	Average rank 2	Average difference	p =	Power r =
face-face-teaching (1) & Zoom Camera (2)	20	17	33.05	32.97	-0.08	1.000	0.003
face-face-teaching (1) & Zoom Avatar (3)	20	18	33.05	17.69	-15.36	0.005	0.512
Zoom Camera (2) & Zoom Avatar (3)	17	18	32.97	17.69	-15.28	0.008	0.510
r > 0.5 = large power							

C. *Analysis of Zoom Fatigue causes*

As described in Section I, a distinction can be made between Zoom Fatigue symptoms and causes. A selection of 5 items from the ZEF Scale was used for the Zoom Fatigue symptoms and used in the questionnaire. As explained in Section III, 2 positive and 2 negative aspects can be selected for the Zoom Fatigue causes, which addresses the differences between virtual learning environments and classic video conferencing systems. Positive aspects are item 6, the opportunity to exchange ideas and network informally, and 7, an inspiring environment. Negative aspects include item 8, having to watch oneself, and 9, discomfort about others seeing one's own video image. Items 6 and 7 can be answered meaningfully in any type of virtual environment. It does not matter whether you have a video environment with a picture or a virtual environment with an Avatar. The situation is different for items 8 and 9, which require a video image and can, therefore, only be answered meaningfully if this virtual environment is available. Three different learning environments were used in the Trend seminar: face-to-face teaching, teaching via Zoom camera, and Zoom Avatar. Questions 6 and 9 are not meaningful for face-to-face teaching, so this learning environment is not included in the following analyses. Items 8 and 9 can only be answered meaningfully for the Zoom camera.

We will now check whether the two items 6 and 7 are related to 1 ‘I felt exhausted after a course’. To do this, these items are correlated with each other. As the number of cases is very low, both Pearson's r and Spearman's Rho are used as shown in Table VI. The feeling of exhaustion (item 1) is related to the opportunity for informal exchange and networking. A correlation coefficient of 0.5 or more is considered a strong correlation. The more the test subjects exchange ideas or network, the higher the perceived exhaustion. For ‘Zoom camera’, only the correlation with Pearson's r is significant, not with Spearman's Rho. The correlation of item 6 with item 1 is, therefore, doubtful. The situation is different for ‘Zoom Avatar’. Here, both correlations are significant. For item 7, all correlations are not significant ($p > 0.05$). There is, therefore, no bivariate correlation between the two items.

TABLE VI. CORRELATION TO GENERAL FATIGUE

	Zoom Camera Pearson's r	Spearman's Rho	Zoom Avatar Pearson's r	Spearman's Rho
Item 6 I had the opportunity for informal exchange and networking in the virtual environment				
	0.581	0.530	0.671	0.642
p =	0.037	0.062	0.003	0.005
N =	13	13	17	17
Item 7 I found the virtual environment stimulating and inspiring				
	0.296	0.168	0.107	0.034
p =	0.351	0.602	0.673	0.894
N =	12	12	18	18

To not only measure the relationship between individual variables, as in the correlation analysis above, a multiple linear regression is also used. This allows us to measure the simultaneous influence of the two items 6 and 7 on the General feeling of exhaustion (item 1). The independent influences of the individual variables on the dependent variable are measured. Item 1 is used as the dependent variable; the independent variables are items 6 and 7. The correlation analysis has shown that the correlations for item 6 vary depending on the learning environment. Therefore, a dummy variable was introduced as a control variable. This controls for any possible influence of the two learning environments. The quality check for the multiple linear regression yielded the following results:

$N = 29$, $R = 0.795$, $R^2 = 0.632$, corrected $R^2 = 0.587$, the model is significant with $p = 0.000$. The R^2 of 0.632 means that 63.2% of the variance of variable F8.1 is explained by the three variables 6, 7 and the dummy variable. This means that the model has very good explanatory power. The results for the individual influences are shown in Table VII.

All three variables are significant with $p \leqslant 0.05$. The β values are of interest for interpretation as they indicate the strength of the influence of the individual variables on the dependent variable. As these values are standardized, they can be compared with each other. Variable 6 has the greatest influence on perceived exhaustion (β=0.814). The opportunity for informal exchange and networking in particular increases exhaustion.

TABLE VII. MULTIPLE LINEAR REGRESSION FOR ITEMS 6 AND 7 TO ITEM 1 GENERAL FATIGUE

Coefficients	Non-standardized coefficients B	Standard Deviation	Standardized coefficients β	T	p =
Constant	2.228	0.370		6.014	0.000
Item 6	0.692	0.144	0.814	4.803	0.000
Item 7	-0.323	0.137	-0.406	-2.354	0.027
Dummy	-0.828	0.235	-0.442	-3.528	0.002
Dependent Variable: Item 1 (General fatigue)					
Item 6: (Networking Opportunities)					
Item 7: (Stimulating Environment)					
Dummy: Zoom Avatar (Zoom Avatar = 1, Zoom Camera = 0)					

However, if the virtual environment is perceived as stimulating and inspiring (item 7, $\beta = -0.406$), this reduces the perceived exhaustion somewhat. However, the level of perceived exhaustion also depends on which virtual learning environment you are in. The 'Zoom Avatar' learning environment lowers General Fatigue compared to the 'Zoom Camera' learning environment with a strength of $\beta = -0.442$.

V. Discussion

This study focuses on the phenomenon of 'Zoom Fatigue', i.e. symptoms of exhaustion caused using online courses. Applied to academic courses, the question was whether different levels of Fatigue occur depending on the learning environment. It was expected that the two online units would differ from face-to-face teaching. However, this is not the case. Rather the Zoom camera environment differs from the other two learning environments. However, the overall level of Fatigue is not particularly high. The five items of Zoom Fatigue on the ZEF scale [Appendix] could be rated on a scale from 1 'strongly disagree' to 5 'strongly agree'. Even though the courses lasted more than 4 hours each day, the mean values of the items ranged between 2.00 and 3.29 for all three teaching environments. For the individual items, the highest mean for General Fatigue (item 1) was 3.6 for face-to-face teaching, followed by Zoom camera at 3.53. It was surprising that face-to-face teaching appeared to cause the most Fatigue, although it was closely followed by the Zoom Camera digital learning environment. Also striking was the significant difference between the Zoom Avatar learning environment and the other two groups. Based on the assumption that online events Generally lead to Fatigue, it was not expected that there would be significant differences between the different virtual environments. Obviously, the form of the virtual environment plays a crucial role, especially the use of cameras in classic videoconferencing systems. The use of Avatars instead of camera images in the still identical 'tile optics' significantly reduces General Fatigue.

The correlations show that there is a significant relationship between networks and perceived Fatigue. The more intense the perceived positive aspects of informal exchange and networking, the higher the perceived Fatigue. Interestingly, however, the multiple linear regression showed that perceived Fatigue decreases the more inspiring the virtual environment is perceived to be. In addition, Fatigue decreases slightly in the 'Zoom Avatar' learning environment.

VI. Conclusions and future work

As described in the previous sections, overall, a relatively low level of Fatigue was observed in the different learning environments. The group of test subjects may be even more resilient due to their relatively young age and higher ability to maintain concentration and receptivity in courses. It is also possible that the intrinsic motivation of master's students is Generally at a high level, as the choice of a Master's degree program is usually a conscious decision. Surprisingly, the value for General exhaustion was highest for the face-to-face program. This seems strange at first, as it was always assumed that longer online courses would lead to higher levels of exhaustion than face-to-face courses. In addition, the results of our own long-term study, which was also carried out as part of this program, show that students clearly prefer face-to-face teaching to online teaching because it allows for personal contact with other students and the tutor, promotes informal exchanges and the risk of distraction is lower [14]. So, it seems that the intensity and, therefore, the effort is higher in face-to-face courses, but at the same time, the students themselves want this intensity. In this context, one could speak of 'self-motivated Fatigue'. The results of the correlation analyses also show a surprising effect of increased Fatigue with good opportunities for informal exchange and networking. Again, this option, which is desired, seems to lead to increased Fatigue, as does face-to-face teaching. However, this Fatigue can be mitigated by an inspiring and stimulating environment. The pending analysis of the qualitative interviews conducted as part of this study may provide further information on these findings. Furthermore, analyses of virtual courses in 2D desktop (gather.town) and 3D desktop (framevr.io), which were also part of this study, are still pending. Also, the results of the qualitative interviews are not included so far, which could be interesting for the perception and identification of the Avatars. Furthermore, it could be interesting to ask about the distracting aspect of using Avatars and virtual environments, as well as the challenge on exams and the active participation of students acting as Avatars.

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Designing Professional Development Workshop to Foster Critical Thinking Skills in Hybrid Learning Environments in Higher Education

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***Abstract*— In an era increasingly shaped by Hybrid Learning (HL) and Artificial Intelligence (AI), equipping pre-service teachers with strong Critical Thinking Skills (CTS) is imperative for effective teaching and lifelong learning. This study presents the design and implementation of a research-based Professional Development (PD) workshop aimed at fostering CTS among pre-service teachers in Hybrid Learning (HL) environments. Grounded in Merrill's First Principles of Instruction and Paul and Elder's Intellectual Standards, the workshop integrates innovative Pedagogical strategies such as, Evidence-Based Learning (EBL), Socratic Questioning (SQ), Game-Based Learning (GBL), Discussion-Based Learning (DBL) and scenario-driven group tasks to promote reflective and analytical thinking. The study employs a qualitative case study methodology, drawing on data from document analysis, semi-structured interviews, and pre-/post-surveys to investigate how teacher candidates and instructors perceive and apply CTS strategies in hybrid contexts. The findings indicate that targeted, interactive PD experiences can enhance pre-service teachers' ability to engage in and facilitate Critical Thinking (CT) in hybrid settings. The paper offers practical implications for instructional designers, teacher educators, and policymakers seeking to support CTS development in the digital age.**

Keywords - critical thinking skills; hybrid learning; pre-service teachers; instructional design; professional development

I. INTRODUCTION

The creation of Professional Development (PD) workshops aimed at enhancing CTS among pre-service teachers within HL environments in higher education is a multifaceted endeavor that requires careful consideration of pedagogical strategies, theoretical frameworks, and the integration of technology. The introduction of advanced tools such as ChatGPT has significantly transformed educational paradigms, enabling personalized learning experiences that cater to individual student needs. This shift underscores the importance of equipping future educators with the ability to critically analyze and adapt their teaching methods to diverse contexts [1]. CT is often defined through cognitive skills and affective dispositions, emphasizing its role as both a generic and domain-specific ability. The transferability of CT across different domains remains a subject of debate, but its presence in science education and other fields highlights its universal applicability. Background knowledge plays a crucial role in fostering CT, as it provides the foundation upon which analytical and reflective thinking can be built [2]. In HL environments, where traditional face-to-face instruction is combined with online modalities, the cultivation of CT becomes even more essential. These settings demand innovative approaches that not only engage students but also challenge them to think independently and critically. Effective teaching strategies for promoting CT include mentoring, authentic problem-solving tasks, dialogue-based methods, and inquiry-driven practices. These approaches encourage educators to evaluate their instructional techniques critically and adapt them to meet the needs of diverse learners. Research has demonstrated that these strategies are effective in enhancing cognitive abilities beyond conventional methods. For instance, mentoring allows pre-service teachers to gain insights into real-world challenges while fostering reflective thinking. Similarly, inquiry-based teaching creates an environment where educators and students collaboratively explore complex issues, thereby nurturing critical analysis. The integration of technology into professional development programs further supports the development of CT skills. Tools like ChatGPT exemplify how artificial intelligence can be leveraged to provide tailored educational experiences. By analyzing individual strengths and weaknesses, these technologies enable pre-service teachers to refine their instructional strategies and address specific learning objectives effectively. Moreover, online discussions facilitated by HL platforms have been shown to enhance students' ability to organize ideas coherently, develop thesis statements, and integrate content across various sections of their work. These discussions serve as a medium for meaningful exchanges that promote critical engagement with subject matter. Professional development workshops designed for pre-service teachers must also consider the audience's prior knowledge, interest in the topic, and stance toward the subject matter. By aligning workshop objectives with these factors - such as informing participants about effective practices or persuading them to adopt new methodologies - educators can better prepare future teachers for the complexities of modern classrooms [3]. Additionally, focusing on content goals like writing argumentative essays or engaging in independent text discussions helps students develop self-sponsored questions about texts and improve their analytical capabilities. The authors emphasize that systemic development in education requires both individual growth among educators and structural changes within institutions. This dual approach ensures that PD programs are not only grounded in research but also adaptable to evolving educational landscapes [4]. HL environments offer unique opportunities for this systemic growth by combining traditional pedagogical methods with innovative technological solutions. By fostering CTS through targeted PD workshops, higher education institutions can prepare pre-service teachers to navigate diverse learning contexts effectively. These efforts contribute to creating a generation of educators who are equipped with the skills necessary for reflective practice and adaptive teaching strategies [5] [6].

The main objective of this study is to examine the instructional strategies and models—including Merrill's Principles and Paul and Elder's Standards—that teaching assistants (TAs) employ to foster CTS in HL environments. Additionally, the study investigates how these strategies influence the development of CTS in pre-service teachers, as well as the challenges that both TAs and students encounter in implementing them effectively.

To guide this inquiry, the study addresses the following research questions. First, how do TAs integrate CTS into the delivery of HL courses in higher education? Second, what strategies do TAs and pre-service teachers perceive as most effective or challenging in fostering CTS within HL environments?

The rest of the paper is structured as follows: Section II reviews related work on CTS and professional development in hybrid environments. Section III outlines the instructional framework combining Merrill's and Paul and Elder's models. Section IV presents the methodology. Section V discusses key findings and implications. Section VI concludes with directions for future research.

II. Literature Review

CT is an essential skill for students in the 21st century, enabling them to analyze information, solve problems, and make informed decisions. CTS encompass the mental processes of discernment, analysis, and evaluation to achieve a logical understanding [7]. It has become even more important that students are taught to think critically, which means it can be facilitated during teaching and learning [8]. It has been suggested that CT should be integrated into pedagogical practices [9]. It is also an important skill that every student needs to have, including elementary students [10]. Therefore, teachers must possess a solid understanding of CT principles and effective strategies for fostering these skills in their students [11].

Effective teaching methods are important for teaching students CTS. One method is to facilitate problem-solving skills in educational settings using Socratic inquiry [12]. This method encourages students to think for themselves and value their own questions [13]. Socratic seminars are one way to promote CT and values clarification [14]. Instructors should ask open-ended questions rather than ones with simple answers [15]. Educators may foster independent and higher-level thought in their pupils by using SQ, which gives them ownership of their learning through conversation, debate, assessment, and material analysis [16].

Moreover, HL environments, which blend face-to-face and online instruction, present unique opportunities and challenges for promoting CT. This method of teaching can create more independent and critical thinkers [17]. Teachers that have the ability to successfully integrate technology can have students be more engaged in the classroom and have the potential to be critical thinkers. However, students' thinking abilities are not always systematically developed because teachers' instructional delivery frequently emphasizes the mastery of concepts or theories [18]. Therefore, teachers require PD opportunities that equip them with the knowledge and skills necessary to design and implement effective instruction that fosters CT in HL environments.

Teachers' beliefs and thought processes greatly affect how well students perform in school and what they accomplish [19]. If teachers are given the proper support and tools, they can have a substantial impact on the growth of students' critical thinking abilities. Schools are responsible for improving students' CTS [20]. Therefore, teachers must have the skills to teach these students in ways that will cause them to think critically and creatively.

PD is often aimed at enhancing student success by increasing teachers' knowledge of the subject matter and improving their teaching methods [21]. Effective PD is essential to help teachers learn and improve the pedagogies needed to teach these skills. Many PD programs, however, seem ineffective in encouraging changes in teachers' practices and student learning [22]. Most existing PD programs tend to be short, lack well-designed structures, and do not seem to provide participants with opportunities to experience Blended Learning (BL) themselves [23]. PD workshop is seen as a crucial way to help teachers improve their skills, knowledge, and effectiveness, leading to a shift from traditional workshops to comprehensive strategies that build teacher capacity in subject matter, pedagogy, and understanding student thinking [24]. PD should provide teachers with chances to use what they're learning in their own teaching and solve problems they encounter in their classrooms [25]. The design of successful PD activities should include follow-up support, active learning opportunities, and the chance for teachers to work together [26]. Designing PD workshop is not about changing teachers' attitudes towards integrating technology or improving their skills with specific technologies [27]. Rather, it involves understanding the nature of technology integration and providing teachers with opportunities to develop the knowledge, skills, and attitudes needed to integrate technology into their teaching [28] [29]. The emphasis should be placed on ensuring that PD workshop is linked to identified teacher needs and that teachers have a say in the type of learning they require to best support their students [22].

Research on CTS in higher education has grown significantly, particularly in response to the shift toward hybrid and online learning environments. Many studies affirm the value of instructional strategies such as SQ, Problem-Based Learning (PBL), and DBL in cultivating CTS across disciplines. Scholars have also emphasized the importance of integrating digital tools and AI technologies into Instructional Design (ID) to enhance learner engagement and Higher-Order Thinking (HOT). However, most of this research remains focused on traditional classroom settings, with relatively few studies addressing CTS development in hybrid environments, especially within pre-service teacher education programs in the U.S. context.

Despite these contributions, several important questions remain unanswered. For instance, there is limited understanding of how pre-service teachers apply CTS-promoting strategies in real-world hybrid classrooms. It is also unclear how instructional models such as Merrill's First Principles or Paul and Elder's Intellectual Standards translate into effective, scalable workshop designs for diverse learner populations. Moreover, few studies have examined how artificial intelligence tools like ChatGPT or adaptive learning platforms can be leveraged to scaffold CTS development among pre-service teachers. These gaps underscore the need to explore not only which instructional strategies work, but also why, how, and under what conditions they are most effective.

The literature reveals a wish list for future research that includes deeper exploration of technology-mediated strategies tailored to hybrid settings, especially those integrating AI and digital feedback tools. There is also a need for empirical studies that examine the long-term impact of PD on CTS, beyond initial knowledge gains. Specifically, the field lacks research on the sustainability of CTS-promoting instructional changes and their transferability across different educational contexts. Additionally, teacher preparation programs often do not systematically equip future educators with models or tools to teach CTS within hybrid or online environments, creating a significant gap in both theory and practice.

This study addresses these gaps by proposing a structured, research-informed PD workshop aimed at pre-service teachers and grounded in two validated instructional frameworks: Paul and Elder's Intellectual Standards and Merrill's First Principles of Instruction. Unlike most studies that focus solely on strategy efficacy, this research also investigates the perceptions, challenges, and implementation experiences of both TAs and pre-service teachers. It goes further by integrating AI tools, such as ChatGPT, to personalize learning and scaffold critical thinking processes. Through document analysis, interviews, and thematic coding, the study offers actionable insights into designing and evaluating PD models that support CTS in hybrid learning environments, thereby advancing the conversation on effective teacher preparation in the digital age.

III. Strategies For Teching and fostering CTS

Integrating CTS into higher education requires effective models, methods, and tools for both instruction and assessment [30] [31]. The COVID-19 pandemic significantly disrupted higher education, leading to the widespread adoption of educational technology, which has played a crucial role in fostering CTS in HL environments [32][33] [34]. CTS is recognized as a key 21st-century competency, prompting educators to integrate HOT skills into classrooms to help students process information critically, make sound judgments, and think creatively [35] [36]. Problem-Based Learning (PBL), which involves engaging with real-world scenarios, has proven to be an effective strategy for fostering CTS in hybrid settings, enhancing students' problem-solving skills and decision-making abilities. Additionally, active learning strategies (see Figure 1 below), such as questioning techniques and discussions, combined with careful instructional design and the strategic use of technology, create dynamic environments that promote CTS [37]. CTS is indispensable across disciplines and requires innovative pedagogical approaches that blend theoretical knowledge with practical, real-world experiences [38].

To address these challenges, educators are encouraged to incorporate HOT skills, as CTS remains a vital 21st-century competency [35]. PBL and active learning strategies, including questioning and discussions, effectively foster CTS in hybrid environments [36] [37]. By combining these approaches with strategic technology use and thoughtful instructional design, educators can create dynamic learning environments that enhance students' critical thinking, decision-making, and problem-solving skills [38].

A review of the literature reveals several effective strategies, including debate, discussion, SQ, project-based learning (PBL), Team-based learning (TBL), PBL, and DBL, to name a few. These strategies, when combined with careful instructional design and the strategic use of technology, can create dynamic learning environments that empower students to think critically, analyze information, and develop well-reasoned perspectives.

IV. Instructional Framework for Fostering Critical Thinking Skills (CTS) in Hybrid Learning Environments

This section presents the theoretical frameworks used to design the PD workshop, integrating cognitive standards and instructional strategies to promote CTS in HL environments.

A. Paul and Elder's Intellectual Standards Model

Paul and Elder's model offers a comprehensive structure for enhancing CTS through nine interrelated intellectual standards: clarity, accuracy, precision, relevance, depth, breadth, logic, significance, and fairness [39] [40]. These standards guide learners in evaluating arguments, questioning assumptions, and applying metacognitive strategies—essential for rational judgment and deep learning, particularly in hybrid contexts [41].

Each standard plays a distinct role: clarity and accuracy ensure understanding and correctness; depth and breadth address complexity and perspective; while logic and fairness guide sound reasoning and unbiased analysis [42] [43] [44] [45]. Their integration supports dialogic teaching methods, such as SQ, which prompt learners to identify assumptions and construct well-reasoned arguments [46] [47].

Additionally, the nine intellectual standards (see Figure 1) guide clear and effective thinking. Clarity ensures ideas are understandable and free of confusion. Accuracy requires statements to be true and verifiable. Precision adds necessary detail and specificity. Relevance ensures each point relates directly to the issue. Depth addresses the complexity of problems, avoiding shallow reasoning. Breadth involves considering multiple viewpoints. Logic ensures that ideas fit together coherently. Significance focuses on what matters most in a discussion. Fairness demands impartiality and respect for all perspectives. Together, these standards support thoughtful, ethical, and reasoned decision-making.

Applied in higher education, especially for pre-service teachers, these standards offer a foundation for designing course content, assignments, and reflective tasks that promote CTS [48] [49]. However, challenges in HL settings include ensuring students' effective use of these standards during digital learning and information-seeking processes.

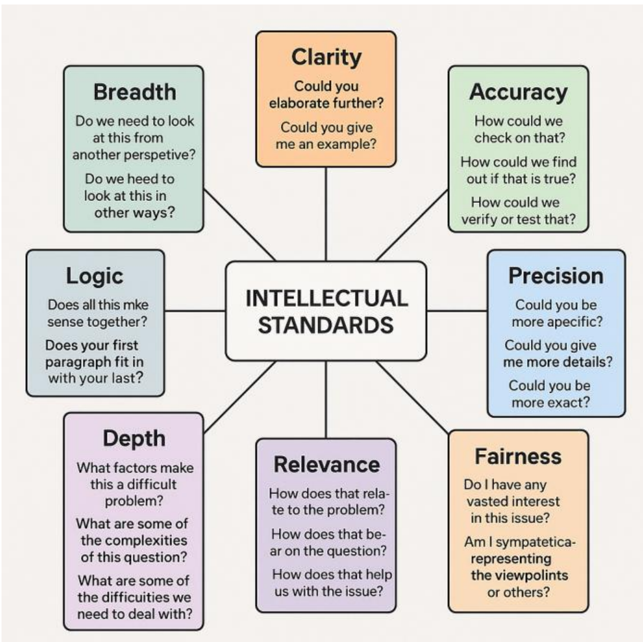

Figure 1. Paul and Elder's model of intellectual standards.

B. *Merrill's First Principles of Instruction*

Merrill's instructional design model complements Paul and Elder by offering a practical framework for structuring active, task-based learning (TBL) in HL environments [50]. It emphasizes four core principles: Activation, Demonstration, Application, and Integration—each supporting the development of CTS by engaging learners in real-world problem-solving [51] [52] [53].

In this study, these principles are applied as follows:

- Activation: Pre-class quizzes and reflective prompts bridge prior knowledge with new content.
- Demonstration: Flipped learning via video-based modules enables self-paced engagement [54].
- Application: In-class tasks, such as case studies and group projects, allow skill practice and feedback.
  Integration: Reflective discussions and scenario-based tasks foster transfer of learning and Higher-Order Thinking (HOT) [55] [56] [57].

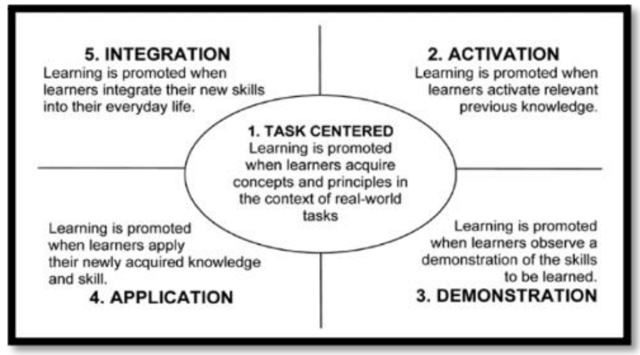

Figure 2. Merrill's First Principles of Instruction.

This research employs both Paul and Elder's standards and Merrill's principles to design a PD workshop that equips pre-service teachers with the tools to foster CTS in hybrid settings. Paul and Elder offer what of CT (cognitive standards), while Merrill provides the how (instructional strategy). Their integration ensures that teachers not only understand and assess ideas critically but also apply this understanding through structured, active learning processes. This framework addresses the pedagogical demands of hybrid education while supporting long-term development of reflective, fair-minded educators.

V. RESEARCH DESIGN AND METHODOLOGY

This study adopts a qualitative case study design to examine how a PD workshop supports pre-service teachers in fostering CTS within HL environments. A case study is ideal for exploring contemporary educational practices within their real-world context, especially when the boundaries between the phenomenon (CTS development) and its environment (hybrid instruction) are blurred. The bounded case is the implementation of a PD workshop in the EDCT 2030 (educational computer technology) course at a Midwestern public university, Ohio University.

Data will be collected during the fall semester 2025 through three qualitative sources: a preliminary open-ended survey, document analysis, and semi-structured interviews. The survey will gather insights into participants' initial understanding of CTS, their teaching experiences, and perceptions of HL. It will also collect demographic information such as age, instructional background, and familiarity with technology. The survey results will inform interview protocol development and document analysis focus.

Following the survey, document analysis will be conducted on instructional materials from the EDCT 2030 course, including syllabi, lesson plans, discussion transcripts, and assignments. These artifacts will be examined using an IRB-approved coding protocol to identify pedagogical strategies, CTS integration, and instructional alignment with hybrid teaching principles.

Semi-structured interviews will be conducted with selected participants to explore how they implemented CTS strategies and reflected on the workshop's impact. Interview questions will be adapted from validated sources and tailored to reflect themes identified in the survey. All interviews will be transcribed and thematically analyzed [58].

The participants will be pre-service teachers enrolled in EDCT 2030: Instructional Technology in Education, a required course for initial licensure. A purposive sampling method will be used to recruit individuals involved in HL environments. Participation is voluntary and conducted under IRB protocols.

At the center of this study is a two-sessions workshop, designed to build CTS instructional competencies. Each session lasts approximately three hours. The first session introduces theoretical models, including Paul and Elder's Intellectual Standards and Merrill's First Principles of Instruction, supported by active learning strategies such as SBL and PBL. The second session emphasizes practical application through role-play, debate, and collaborative activity design using techniques like GBL and PBL. Participants reflect on these experiences and discuss challenges and implementation strategies.

The effectiveness of the workshop will be assessed through participant reflections and feedback forms. Data will be analyzed through thematic analysis using a three-phase process: open coding, axial coding, and selective coding. Triangulation of survey, document, and interview data will strengthen the study's trustworthiness. Additional strategies to ensure rigor include member checking, peer debriefing, and an audit trail.

VI. Expected Outcomes and Significance

This study is expected to yield valuable insights into how PD workshops can enhance pre-service teachers' ability to foster CTS within HL contexts. By engaging participants in a structured, interactive workshop grounded in established instructional models—such as Paul and Elder's Intellectual Standards and Merrill's First Principles of Instruction—the study anticipates notable shifts in participants' pedagogical knowledge, instructional design choices, and classroom implementation of CTS strategies.

It is anticipated that pre-service teachers will demonstrate increased awareness and understanding of CTS as a pedagogical goal, along with a greater ability to translate theory into practice through active learning methods such as PBL, SBL, DBL and GBL. Additionally, participants are expected to gain confidence in designing and facilitating learning experiences that challenge students to reason, analyze, and reflect critically.

The study also expects to identify practical and transferable strategies for embedding CTS within digital and hybrid instructional environments. These findings will be informed by a thematic analysis of interviews, surveys, and instructional documents and will offer evidence-based recommendations for teacher educators and curriculum designers seeking to prepare future teachers for 21st-century educational demands.

The broader significance of this study lies in its contribution to the fields of teacher education, instructional design, and PD. By emphasizing CT in hybrid settings, this research aligns with national and global priorities for HOT and digital pedagogy. Its outcomes may inform institutional policies on faculty training, program development, and technology integration, thereby supporting the creation of adaptable, reflective, and critically engaged educators.

To further illustrate the anticipated outcomes and persistent challenges of the professional development workshop, Table I summarizes key focus areas, observed benefits, and identified gaps in implementing CTS strategies in hybrid learning environments.

TABLE I. WORKSHOP OUTCOMES AND GAPS

Focus Area	Observed Outcomes	Identified Gaps
Instructional Strategy Integration	Increased use of Socratic questioning and scenario-based learning	Need for consistent application across sessions
Pre-service Teacher Engagement	Improved confidence in applying CTS	Limited opportunities for collaborative peer
Use of AI and Digital Tools	Effective use of tools like ChatGPT for reflection and feedback	Variability in access and digital literacy levels
Sustainability of CTS Practices	Short-term improvement in instructional	Lack of long-term follow-up and support mechanisms
Institutional Support	Positive feedback from participants on PD design	Insufficient policy-level incentives for CTS integration

Ultimately, this study contributes to the ongoing effort to equip educators with the tools, frameworks, and dispositions needed to prepare students for complex, real-world challenges through thoughtful, critical engagement.

VII. Discussion and Limitations

This study provides valuable insights into fostering CTS in HL environments; however, several limitations must be acknowledged. Conducted solely at Patton College of Education at Ohio University, its institutional specificity may limit the generalizability of findings. As a qualitative case study, the research relies on participants' self-reported data and researcher interpretations, which may introduce bias despite methodological safeguards. The study captures short-term outcomes and does not assess long-term pedagogical shifts. Variability in HL technologies, instructional methods, and students' digital literacy may also affect the consistency of results. Furthermore, focusing on the EDCT 2030 course and Teaching Assistants may not fully represent broader

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educational contexts or faculty perspectives in other disciplines. Finally, given the fast-paced evolution of AI and digital tools in education, some practices examined may quickly become outdated. Ongoing research is essential to monitor technological changes and their implications for promoting CTS in higher education.

VIII. CONCLUSION

This article examines how a PD workshop can help teachers foster CTS in HL environments. Using a qualitative case study design, the study highlights the importance of theory-based, practical instructional strategies grounded in Paul and Elder's Intellectual Standards and Merrill's First Principles of Instruction.

Findings are expected to show that active learning methods—such as case studies, PBL, and collaborative tasks—support pre-service teachers in applying theory to practice. The workshop helps build educators' confidence and competence in integrating CTS into technology-mediated learning.

The study also explores the use of multimedia and AI tools. While some participants may feel equipped to use them to enhance CTS, others may reveal gaps in training, suggesting a need for continued professional support.

This research adds to the field of teacher education by offering practical insights and advocating for evidence-based approaches to developing CTS in HL settings.

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