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RESEARCH

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Learning critical thinking skills with online bite-sized videos: a qualitative account of students' perceptions

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Abstract

Learning to think critically is a key educational goal for higher education that presents a significant challenge for many students. Surprisingly, few studies have reported students' views and perceptions towards instructional methods in critical thinking. The current study explored university students' experiences and perceptions towards an online intervention designed to improve critical thinking skills. The intervention employed video-based learning to introduce four common informal logical fallacies to students across two micro-learning episodes administered online. We conducted semi-structured interviews with 30 university students to gain insight into four key areas: i) the perceived usefulness of the intervention for critical thinking development, ii) the presentation of learning materials, iii) the factors impacting their engagement, iv) and the potential of this approach to support mainstream provisions. We identified four main themes using thematic analysis: 1) building understanding and awareness of critical thinking, 2) effective video design and presentation, 3) valuing technology-enhanced learning approach, and 4) divergent experiences derived from the practice phase. These themes encapsulate students' experiences of learning critical thinking as a highly sophisticated skill within an online learning environment and their preferences towards an effective video design. We discuss the implications of these findings for future pedagogical research and training of critical thinking in higher education.

Keywords: Critical thinking, Video-based learning, Technology-enhanced learning, Higher education, Qualitative analysis, Thematic analysis

Introduction

Critical thinking refers to identifying, analysing, and evaluating claims as well as providing explanations or justifications for the conclusions drawn (Abrami et al., 2015; Bensley et al., 2010). This multifaceted skill also involves metacognitive processes; that is, it builds



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on conscious awareness of one's thinking patterns to produce conclusions, arguments or solutions to problems (Dwyer et al., 2014). Solid critical thinking skills are associated with enhanced employability, better real-life decision-making, and higher financial literacy (ten Dam & Volman, 2004). Therefore, higher education institutions identify critical thinking as a key learning outcome for their graduates (Hatcher, 2011) and highlight the building of critical thinking skills as one of the most important components of university education (DeAngelo et al., 2009).

However, despite higher education providers' emphasis on critical thinking, it is unclear which instructional strategies effectively promote these skills (Zhao et al., 2016). Some researchers claim that critical thinking education should adopt a so-called explicit approach, which teaches students generic metacognitive skills, such as analysing the strength of arguments, evaluating the credibility of claims, or identifying flaws in arguments (Ennis, 1989). On the other hand, other researchers advocate that implicit teaching approaches, which emphasise on integrating critical thinking into specific course materials, are more efficient than approaches aiming to build general critical thinking skills (Ennis, 1989; Zhao et al., 2016). Nevertheless, the complexity and varying conceptualisation of critical thinking across disciplines represent a significant challenge in teaching critical thinking skills (Broadbear, 2003; Scriven & Paul, 2007).

There is extensive literature on educational interventions to promote critical thinking skills (Abrami et al., 2008; Niu et al., 2013). There appears to be evidence that positive learning outcomes can be achieved when employing elements such as defining clear learning targets, providing examples and counterexamples of a concept, using exercises to train on learning targets, and providing immediate feedback (Bensley et al., 2010). However, crucially, it is challenging to implement these components within conventional lecturer-led instructional settings, in which the contact time between staff and students is limited (Mandernach, 2006; Peter, 2012).

Furthermore, the shift of the higher education sector to online or blended learning following the outbreak of Coronavirus, COVID-19 (WHO, 2020) has presented an additional challenge to teaching critical thinking skills. Students' unfamiliarity with online learning environments creates barriers to their engagement in critical thinking tasks through online discussions, debates, and focus group meetings (MacKnight, 2000; Tathahira, 2020). Importantly, there is a scarcity of research on students' learning experiences with online teaching approaches for critical thinking (Guiller et al., 2008; Richardson & Ice, 2010). More precisely, while the COVID-19 pandemic saw a rise in the popularity of video learning within the higher education setting, most research on the educational uses of videos has focused primarily on subject-relevant knowledge (Carmichael et al., 2018). As a result, little is known about the potential of video-based learning to promote critical thinking skills, which are domain-general and high-level. We

also know little about online learning designs and elements of teaching that could foster critical thinking skills in online learning environments, as well as student experiences with these (Carmichael et al., 2018).

The current study addressed, exactly, the latter research gap. It employed qualitative methods to contribute towards a deeper understanding of the subjective experience, views, and perceptions of students from a UK university who participated in a brief online intervention for critical thinking (Tan et al., 2022; Tan et al., 2023c). Such subjective experiences and views help identify specific elements that are particularly engaging or challenging, and provide a basis for refining and enhancing the effectiveness of educational approaches aiming at critical thinking. Furthermore, student's accounts constitute empirical evidence on the motivational and engagement processes that may drive learning and offers important insights into the contextual factors that influence the effectiveness of learning interventions. These insights can inform the design of more effective and personalised educational tools (Choi & Johnson, 2005; Daniela et al., 2018). Therefore, the contributions of the current study are two-fold. Firstly, it advances the understanding of critical thinking skill development in online environments. Secondly, it adds to the broader literature base of self-directed learning theories by exploring the elements that students perceive as crucial for a positive learning experience in online learning environments.

The critical thinking intervention was administered to the participants of the study during the second COVID-19 lockdown restrictions applied in the UK between February and April 2021. It focused on common reasoning errors referred to as informal logical fallacies and thought to be an important component of critical thinking (Carey, 2000). In the intervention, informal fallacies involved arguments that are "*psychologically* persuasive but *logically* incorrect" (Copy & Burgess-Jackson, 1996, p. 97). Four common logical fallacies ('appeal to ignorance', 'bandwagon', 'false cause', and 'hasty generalisation') were introduced in the form of two bite-sized learning episodes (20 minutes) via the online Qualtrics platform (Qualtrics, Provo, UT).

The current study is part of the process evaluation for a larger intervention project, which implemented a technology-enhanced learning program aimed at improving critical thinking skills of higher education students. Tan et al. (2023c) reported quantitative results on the impact of the intervention on student's learning outcomes; the current study used qualitative methods to explore students' experiences with the intervention. Below, we provide an overview of the main elements used in the online critical thinking intervention.

Main elements of the online critical thinking intervention

Video-based learning

The critical thinking intervention (Tan et al., 2022; Tan et al., 2023c) was primarily based on a video-based learning approach. This approach was chosen for its flexibility in supporting ubiquitous learning and in addressing limitations of time and space in the face-to-face classroom (Syed et al., 2020). Video-based learning fits into the context of higher education settings that rely heavily on e-learning and is widely used in higher education settings to support diverse pedagogical strategies, including flipped classrooms (Zainuddin & Halili, 2016) and blended learning sessions (Yousef et al., 2014). It is available in various forms, including pre-recorded lectures (Jensen, 2011), tutorial videos (Hoogerheide et al., 2016), and knowledge video clips (Carmichael et al., 2018). The benefits of video-based learning have been well reported in extensive research to enhance students' engagement (Stockwell et al., 2015), academic performance (Tan et al., 2023a; Tan et al., 2023b), and learning motivation (Hill & Nelson, 2011). Students generally perceive video learning to be an enjoyable and flexible approach (Salina et al., 2012; Tan et al., 2023a; Tan et al., 2023b). Within the critical thinking intervention (Tan et al., 2022; Tan et al., 2023c), video-based learning introduces students to the definition of arguments and structural features of informal fallacies, allowing them to apply the critical thinking skills learned across different domains.

Theoretically, the benefits of video-based learning have been attributed to the simultaneous presentation of visual and auditory information. According to the dual processing theory of working memory, learning occurs more effectively when information is presented across dual channels (visual and auditory) due to the limited information processing capacity of each channel (Mayer & Moreno, 1998). Therefore, the integration of graphic images and audio narration in a video-learning session facilitates the organisation of information that is more suitable to be stored in long-term memory (Clark & Mayer, 2016) and results in more meaningful learning (Mayer, 2001).

In this intervention, the instructional videos were animated videos produced through the PowToon platform, which used on-screen text combined with visuals, music, and animation effects. In our design, we combined these elements while adhering to the coherence principle of multimedia design (Mayer & Fiorella, 2014), that is, ensuring a harmonious integration of visuals and text to prevent cognitive overload and enhance information retention by maintaining a direct correspondence between visual elements and textual explanations. Crucially, a narration element, which is often implemented in order to integrate audio and visual components to optimise learning, was not used in our videos. This design feature reflected, partly, the circumstances during which the research was conducted, specifically, the constraints posed by COVID-19 lockdowns, which hindered

our capacity to conduct live audio or video recordings featuring a presenter. Consequently, the results of this study are especially relevant to understanding the learning experiences of students with designs based on animated videos, not utilising a presenter or narration.

Bite-sized videos and micro-learning sessions

The video-based learning approach has been integrated within micro-learning sessions, through bite-sized videos to facilitate knowledge retention. Bite-sized videos focus on presenting information in smaller chunks to maximise students' overall engagement time (Brame, 2016) and avoid cognitive overloading (Khong & Kabilan, 2022). Past research has found that bite-size videos are more engaging and likeable by students than longer ones (Carmichael et al., 2018), with videos of less than 6 minutes reaching up to a 100% engagement rate (Guo et al., 2014).

Precision teaching

Another element integrated within the online critical thinking intervention is Precision Teaching (PT). PT refers to a systematic framework that helps to facilitate self-monitoring of learning and evaluation of teaching effectiveness (Kubina & Yurich, 2012). PT measures *fluency* as evidence of learning by taking into account both accuracy and speed when performing a skill. This approach to measuring performance is important given that fluency is a prerequisite for more advanced skills (Kubina & Morrison, 2000) and is also associated with many desirable learning outcomes such as skill retention, transfer of skills in novel contexts, and the ability to perform the skill for a longer duration (Binder, 1996; Kubina & Yurich, 2012). Within the intervention, PT provides the active learning element by presenting students with questions or prompts that help them monitor their own learning and become aware of the key learning targets. PT also changed the online learning intervention from solely a passive video-viewing activity into active knowledge construction.

There is ample evidence that PT can be utilised successfully to teach a wide variety of skills, such as oral reading fluency (Griffin & Murtagh, 2015; Lambe et al., 2015), mathematics (Hayden & McLaughlin, 2004), statistics (Tan et al., 2023b) and academic terminologies (Stockwell & Eshleman, 2010). Most of these studies utilised so-called frequency-building, an approach informed by the PT framework to train fluency in skills. Frequency-building uses short and repetitive tasks as practice coupled with performance feedback following each task to build fluency in the targeted skills (Lokke et al., 2008). This approach enables students to monitor their learning and supports skill acquisition in a time-efficient way (Kubina & Yurich, 2012).

Problem-based training

Within educational settings, the application of acquired critical thinking skills to practical or subject-specific areas is not typically an intuitive process (Paul & Elder, 2009). Studies emphasise the necessity of infusing critical thinking training within content-focused courses or instructions (Braun, 2004; Gray, 1993; Ikuenobe, 2001) to enable students to grasp ‘how to think’ rather than merely ‘what to think’ (Clement, 1979). Halpern (1998) further proposed a model fostering trans-contextual learning of critical thinking skills, supporting the evidence of problem-based training by scaffolding learners’ application of these skills in real-world scenarios. Problem-based training engages students in real-world challenges to enhance their capacity for integrating knowledge, thinking independently, and solving problems diligently (Posner et al., 2023).

A synergistic approach integrating problem-based training with other instructional methodologies is essential to bridge the knowledge and application gap within critical thinking. This integrated approach facilitates the transfer and practical application of critical thinking skills across diverse domains. In the current study intervention, PT was combined with problem-based training to further support the transfer and application of critical thinking beyond the context where training was conducted.

Overview of the intervention evaluation and summary of quantitative findings

The current study forms part of the process evaluation of a wider intervention-based project. It employed qualitative methods to investigate the subjective experience, views, and perceptions of students who participated in this technology-enhanced learning intervention for critical thinking. Other aspects of our evaluation efforts include a quantitative study by Tan et al. (2023c) that evaluated the effectiveness of this critical thinking intervention with specific measures on learning outcomes. Below, we provide an overview of the intervention evaluation and a summary of quantitative findings.

The intervention consisted of two learning episodes administered online to 57 university students. In each learning episode, participants completed the following parts: i) a quantitative pre-episode test; ii) a 3-minute bite-sized animated learning video; iii) practice on the learning material of the pre-episode test; and iv) a quantitative post-episode test. The practice condition differed across three groups: a self-directed learning control group, a Precision Teaching (PT) intervention group, and a PT+ intervention group. The two PT intervention groups completed fluency training, involving short and repetitive practice rounds with feedback to establish fluency in fallacy identification, with the addition of problem-based training for the PT+ group. The control group received identical instructional materials but was told to complete the practice at their own pace. The

flowchart and experimental design were explained in the quantitative part of the study (Tan et al., 2023c).

The results of Tan et al. (2023c) indicated comparable improvements in fallacy identification post-intervention across all three groups, suggesting that the micro-learning sessions worked equally well in supporting the learning of fallacy-identification skills regardless of whether the practice is PT-based or not. Furthermore, these advantages appeared to be more beneficial for students who struggle, as lower-scoring participants showed higher gains than high-scoring participants. The quantitative results also showed benefits in retention for all with the follow-up assessment one week after, and also showed comparable results between groups. Importantly, the two PT groups performed better in the domain-general fallacy-identification assessment post-intervention than the control, suggesting that the integration of video-based learning and PT practice are more effective in supporting the transfers of skills in novel problem-solving contexts.

Current study

While the quantitative study of Tan et al. (2023c) showed that the intervention improved fallacy identification, the evaluation only considered quantifiable learning outcomes. To strengthen the available evidence on the effectiveness of the intervention, it is important to conduct a more thorough investigation that includes students' perceptions on the intervention's significance as a whole, irrespective of the experimental conditions they were assigned to. It is also crucial to understand how students perceive each intervention element to inform the practicality of the intervention. This process would provide a more comprehensive understanding of the intervention's usefulness, resourcefulness, and relevancy. It would also inform the development of future iterations of the intervention maximising its effectiveness (Cheetham, 1992; Moore et al., 2015).

Hence, here, we conducted a series of interviews with participating students in the intervention to address the four research questions:

1. What are students' perceptions of the usefulness of this intervention for developing critical thinking skills?
2. What are students' views and preferences towards specific elements of this intervention, such as the online bite-sized learning design, the absence of a learning instructor, and the use of technology-enhanced learning models with intertwined videos and online practice elements?
3. How do students account for their judgements and preferences?
4. What do students think about the potential of this approach to support mainstream provisions?

Additionally, we also explored students' learning experiences when they were exposed to a specific practice phase. That is, a self-directed learning control group, a PT intervention

group that received a timed-based frequency-building practice aiming to increase the rate of fallacy identification, and a PT+ intervention group that received an untimed problem-based training in addition to the timed-based frequency-building practice. Hence, the final research question guided this exploration:

5. What are students' perceptions of frequency-building and problem-based training on their abilities to apply critical thinking skills?

Research paradigm

We adopted a pragmatism research paradigm for this study (Kaushik & Walsh, 2019). Ontologically, pragmatism recognises that reality is multifaceted and shaped by subjective experiences. This paradigm acknowledges that individual realities, especially in real-world situations, are constructed through people's interactions and experiences (Kaushik & Walsh, 2019). Within our study, this ontological stance aligns with the aim of evaluating how students' experiences with the online intervention shape their understanding and influence the development of their critical thinking skills. The recognition that these diverse experiences contribute to multiple realities motivated our study's goal of complementing an evaluation of the intervention's quantifiable learning outcomes (Tan et al., 2023c) with a comprehensive assessment based on students' perspectives.

Epistemologically, pragmatism views knowledge as situated within social interactions and constructed through subjective viewpoints. In this study, the epistemological stance supports the exploration and interpretation of participants' experiences with the online intervention. By focusing on these perspectives, our approach sought to understand how students made sense of their experiences with the intervention. This emphasis on subjective understanding aligns with the study's objective of assessing not only the effectiveness of the intervention but also how participants' individual insights contribute to a broader understanding of its impact on critical thinking education.

Methodologically, pragmatism allows for flexibility in the choice of research methods, focusing on selecting the most appropriate tools to answer the research questions (Feilzer, 2010). This paradigm transcends the traditional divide between quantitative and qualitative methods, emphasising the importance of using whichever approach best addresses the research aims. In our study, we applied a mixed-methods approach, collecting data through semi-structured interviews and analysing it both qualitatively and quantitatively. Specifically, we used qualitative thematic analysis to explore the themes emerging from the students' experiences and supplemented this with a quantitative analysis to assess the frequency of different themes. This dual approach enabled us to answer key questions about the intervention's effectiveness, focusing on understanding how, to what extent, and for whom the intervention worked (Kaushik & Walsh, 2019).

The qualitative analysis allowed us to interpret participants' perspectives on the development and implementation of the intervention, while the quantitative analysis provided insight into the prevalence of certain views, identifying patterns within the data. This integrated method offered a holistic understanding of the students' experiences, contributing to a more comprehensive evaluation of the intervention. Although some researchers, like Braun and Clarke (2022), argue that quantification may diminish the depth of qualitative findings, our pragmatic stance views this concern as context-dependent. Pragmatism suggests that, in certain cases, numerical data can provide valuable support, particularly when claims are made using terms such as "many" or "some."

Motivated by these considerations and in response to potential concerns, we conducted an incidence analysis of the interview transcripts, which is presented in a table accompanying the primary qualitative thematic analyses. These results provide readers with supplementary information that extends the discussion of themes and subthemes emergent from the qualitative analysis and enables them to assess for themselves whether including qualitative and quantitative findings adds to the study's value. From this pragmatist perspective, integrating qualitative and quantitative analyses constitutes a transparent methodological approach that benefits our endeavour to address our research questions comprehensively.

Method

Recruitment

All participants received an invitation email from the primary researcher on the last day of the intervention. The email stated our intention to interview them and collect data relating to their views and experiences using the technology-enhanced intervention for critical thinking. Participants had the option to opt-out if they did not wish to be interviewed. This study received ethical approval from the University's Psychology Department Research Ethics Committee.

Participants

Thirty university students from the North West of England (21 females, 8 males, 1 prefer not to say) with a mean age of 25 years ($SD = 3.11$; range 19-38 years old) completed the interviews. Participants consisted of 15 undergraduate students, 8 master's students, and 7 doctorate students. Table 1 shows details of the course titles that participants were enrolled in.

Table 1 Details of the participants' course titles

Course titles	<i>N</i>
Psychology	16
Health & Social Care	5
Humanities	3
Business & Economics	2
Engineering	1
Law	1
Unknown	2

Procedure

Interviews were held virtually through a video conferencing platform (i.e., Zoom) with the primary researcher at a mutually convenient time. Participants were briefed on the purpose of the interviews and asked to provide consent for the data to be audio recorded. Following this, open-ended questions were asked to explore in greater detail the following areas: i) participants' experiences from their involvement in this study (e.g., "Which three words would you use to describe the study?"); ii) their perceived effectiveness of the intervention on improving critical thinking (e.g., "What are the changes on your critical thinking skills after taking part in the study?"); iii) their views on the potential of this intervention to support academic work and daily life (e.g., "How relevant are the skills that you learnt from this study to your academic work and daily life?"); iv) their views towards video-based learning (e.g., "How do you feel about the materials that were presented in the videos?", "What do you think about the length of these videos?"); and v) their views towards the necessity of a video instructor (e.g., "Would you prefer information to be presented with or without an instructor in the future?"). Interviews lasted between 7 minutes and 48 seconds to 22 minutes and 5 seconds. The audio recordings of the interviews were transcribed in full for data analysis.

Interview protocol

The interview protocol was developed based on an extensive review of the literature on critical thinking intervention and online learning. Key themes and questions were derived from previous studies that explored similar educational interventions (Tan et al., 2023a; Tan et al., 2023b). The protocol was then adapted to fit the specific context of our study, focusing on the unique aspects of video-based learning, precision teaching practice, problem-based training as well as the subjective experiences of students in a UK university.

The semi-structured interview protocol included open-ended questions designed to elicit detailed responses from participants about their experiences with the online critical thinking intervention. The questions aimed to explore four dimensions of the students' learning experiences, including: i) the perceived usefulness of the intervention for critical thinking development, ii) the presentation of learning materials, iii) the factors impacting

their engagement, iv) and the potential of this approach to support mainstream provisions. Table 2 details the interview protocol for this study.

Table 2 Interview protocol

Interview Protocol
<p><i>Introduction</i></p> <p>“Thank you for participating in this interview. The purpose of this interview is to understand your experiences with the online critical thinking intervention you participated in.”</p> <p>“Your responses will be recorded and kept confidential. Do you have any questions for me before I proceed with the interview?”</p>
<p><i>Background Information</i></p> <p>“Can you tell me a bit about yourself and your academic background?”</p>
<p><i>Participants’ Experience</i></p> <p>“Did you enjoy taking part in the study?”</p> <p>“What are the three important concepts that you gain from the study?”</p>
<p><i>Perceived Effectiveness of the Intervention</i></p> <p>“How do you feel about your critical thinking skills now after taking part in the study?”</p> <p>“What is the key component of the intervention that has contributed to this improvement in your critical thinking skill (if any)?”</p>
<p><i>Relevance to Academic Work and Daily Life</i></p> <p>“Are there any other outcomes and skills you feel that these sessions have helped you achieve/develop?”</p>
<p><i>Views on Video-Based Learning</i></p> <p>“How do you feel about the material that was presented in the videos?”</p> <p>“What do you think about the video length (approx. 3 mins) in this intervention?”</p> <p>“What is your preference regarding information presented in video format versus text?”</p> <p>“Would you prefer information to be presented without an instructor or with an instructor in the future?”</p> <p>“How do you think video-based resources can be used in a higher education setting?”</p> <p>“How will you use a video-based resource like this in the future?”</p>
<p><i>Views on Practice Sessions</i></p> <p>“How do you feel about the practice sessions within the session?”</p> <p>“How would you comment about your performance across different practice trials?”</p> <p>“How helpful is the feedback within the practice sessions to you?”</p> <p>“Across the two unit, the first unit we introduce different definitions of the fallacy. And then in the second unit, we talk about the example of fallacy. Which one do you think it’s more helpful in terms of improving your critical thinking skill?”</p> <p>“You are put into a scenario where you have like, one minute timing to complete as much questions as you can. How do you feel about that part of the studies?” (participants in PT & PT+ intervention groups only)</p> <p>“You are in the pilot group of the situation judgment practice. Do you think that that part of practice is necessary to help you learning the concept?” (participants in PT+ intervention group only)</p>
<p><i>Applicability Beyond University</i></p> <p>“Do you think this video-based learning scheme can be used in other modules too, or beyond university?”</p>
<p><i>Suggestions for Improvement</i></p> <p>“If you are designing a similar scheme, how will you do it?”</p> <p>“Would you suggest any change or feature of the scheme? Is there anything that you will omit or add to the intervention?”</p>
<p><i>Conclusion</i></p> <p>“Is there anything else you would like to add about your experience with the online critical thinking intervention?”</p> <p>“Thank you for your time and insights.”</p>

Analytic approach

The qualitative data obtained from the semi-structured interviews were analysed using the six stages of thematic analysis as outlined by Braun and Clarke (2006). To begin, each interview transcript was read repeatedly to ensure researchers were familiar with the data set. Next, the researchers made note of any salient comments and coded the entire dataset with initial themes that aimed to capture the key features of the dataset. After this, researchers examined the codes to generate potential themes. Finally, the researchers refined the selected themes and reported these with supporting quotes within this current paper.

This whole process led to the development of the thematic map of Figure 1 depicting the hierarchy of the four main themes and sub-themes.

Based on our pragmatist approach, we also tabulated the frequency of responses for each theme and subtheme to supplement the qualitative data. This process resulted in an incidental table (Table 3), which shows the number of participants contributing to the four main themes and subthemes.

Analysis

Theme 1: Building understanding and awareness of critical thinking

The participants generally expressed highly positive experiences, particularly in their descriptions of the study. When asked to provide three words to describe the study, many participants used the word “interesting”. Other frequently mentioned words were: “*educational*”, “*informative*”, “*useful*”, “*clear*”, “*engaging*”, and “*easy*”.

Participants attributed their positive experiences to two primary factors. Firstly, they appreciated that the study introduced new learning opportunities, and secondly, it improved their perceptions towards critical thinking.

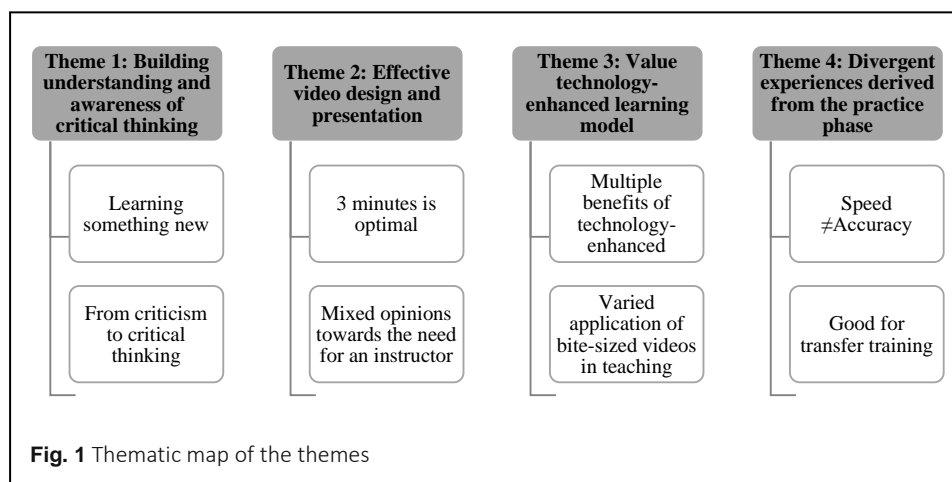


Table 3 Overview of the frequency of responses for each theme and subtheme

Themes	n of participants contributing
Theme 1: Building understanding and awareness of critical thinking	
Subtheme 1.1: Learning something new	24 (out of 30)
Ability to identify logical fallacies improved between the first and second learning sessions	5 (out of 24)
Skill taught is relevant to improving academic writing	9 (out of 24)
Subtheme 1.2: From criticism to critical thinking	15 (out of 30)
Developed more awareness about critical thinking	6 (out of 15)
Helped reassess their previously overestimated CT abilities	4 (out of 15)
No improvement or not sure whether there was improvement in CT	6 (out of 30)
Theme 2: Effective video design and presentation	
Prefer information to be presented in videos than in text	22 (out of 30)
Subtheme 2.1: 3 minutes is optimal!	23 (out of 30)
Suggestions for improving the learning material (i.e., reduce the amount of information presented & pace of the presentation)	4 (out of 23)
Subtheme 2.2: Mixed opinions towards the need for an instructor	
Do not prefer the involvement of a video instructor	10 (out of 30)
Prefer the involvement of a video instructor	11 (out of 30)
Theme 3: Value technology-enhanced learning model	
Subtheme 3.1: Multiple benefits of technology-enhanced learning	20 (out of 30)
Subtheme 3.2: Varied applications of bite-sized videos in teaching	13 (out of 30)
Reviewing and revising subject materials that are challenging	4 (out of 13)
Introducing new topics to novice learners	4 (out of 13)
Theme 4: Divergent experiences derived from the practice phase	
Subtheme 4.1: Speed ≠ Accuracy	
Enjoyed having this challenge to perform under time pressure	11 (out of 30)
Time pressure	14 (out of 30)
Subtheme 4.2: Good for transfer training	9 (out of 30)

Learning something new

The majority of participants indicated that the study introduced them to new terminologies of informal logical fallacies after completing two bite-sized learning episodes. The following quotes highlight the participant's initial unfamiliarity with logical fallacies and the subsequent acquisition of knowledge facilitated by the intervention. The simplicity and clarity with which the material was presented seem to have played a crucial role in making the learning process accessible and effective:

"I didn't know anything about fallacies before doing it. I now know some information about that. And, it (the intervention) broke it down in quite an easy way for me to learn it." (P3009)

"A lot of the terms, I've never come across before. It (the intervention) helps like enrich my understanding towards the use of certain language and how to make arguments stronger." (P3019)

“I haven’t really thought about logical fallacies too much. And it was quite interesting to just learn something new and then apply it.” (P3021)

Some participants also perceived that their ability to identify logical fallacies improved between the first and second learning sessions. For example, Participant P1020 linked their improvements to completing the post-test in less time than the pre-test:

“I understood a lot more, I think. And when I did the post-test, it took me a lot less time as well, because the first one, I didn’t really have a clue. So I was reading things over and over again. Whereas the second time I did it in the post-test, I just kind of knew, I think that I improved.”

Other participants suggested that they gained a better understanding of the relevant concepts. Participant P3011 also highlights that time can aid in the consolidation of new knowledge:

“At the beginning, I thought I was confused between the four categories. But then, the next day, I was a little bit aware of what everything meant. So I was like, yes, I actually was more confident answering them.”

Further to this, some participants indicated that the skill of identifying logical fallacies could help improve their academic writing and was relevant for both undergraduate and postgraduate levels. The ability to identify logical fallacies is fundamental for critical evaluation and academic writing. This skill enables students to construct more robust arguments and critique existing ones, which is crucial for academic success.

“Some of the things (times) is that if you don’t know about these logical fallacies, and you’re probably not, you’re not gonna be looking for them. And you need to look for them in order to diagnose. If you need to critically evaluate, this one I think it would be useful especially for the undergraduates.” (P2008)

“So as a PhD student, critical thinking is like absolutely essential. Like it’s, it’s 100% expected in your thesis. And so I need to not only be able to think critically, and express my thoughts in my writing, but I also need to make sure that I’m avoiding these logical fallacies and that I’m identifying them in other sources so that I can be critical of the structure of their arguments where necessary.” (P2002)

The participants also commented that the fallacies introduced in this intervention were applicable to their daily lives, particularly when constructing an argument or reading newspaper articles.

“I would say, it’s very helpful now that I know these terms, because it will help me recognise how certain arguments or certain points are not as strong or maybe not valid, and how not to use them as well, like how to avoid using like proposing arguments in a certain way as well.” (P3019)

“I would say like, in real life, it’s still really relevant. Because when you read newspaper articles, or when you watch TV, or when you see documentaries, I

think, I mean, this (fallacies) can be valid anywhere, especially when you talk to people.” (P3023)

The participants’ insights reveal a pivotal transformation in their cognitive approach to evaluating arguments. This shift aligns with Ennis’s (1993) definition of critical thinking as a reflective and reasoned judgment. By introducing the concept of logical fallacies, the intervention empowered students to deconstruct everyday arguments critically, a skill integral to fostering independent thinking. However, it was noted by one participant that augmenting the benefits of this intervention could be achieved by incorporating a reflective task at its conclusion:

“Maybe some reflections, maybe helpful. I think it’s just based on my experience on the online courses I realized that reflections are quite important. In terms of like, recentering your goals in what you want to get off the course or what you want to get out of this experience?.” (P2024)

From criticism to critical thinking

In addition to learning something new, participants also stated that the intervention helped to alter their perceptions towards critical thinking. Specifically, they noted that the concepts of critical thinking were previously confusing to them, and there were misconceptions that critical thinking only emphasised criticism or the identification of limitations of a certain approach or theory.

“I think it will help me because I understand the basics like the four different logical fallacies. Because when I was doing critical thinking work in the past, I kind of I was just trying to critique everything, but I didn’t really understand why I was doing it. Whereas I feel like this has helped me to actually understand a little bit more.” (P1020)

“I think that it could be really useful for explaining critical thinking, because a lot of my colleagues and I, at the end of our assignments that like the feedback was, oh, you need more critical thinking. And we were wondering, like, what you mean, I think I used it already, you know. So I mean, even for the critical thinking itself, as it (the intervention) was like, exactly as it was, I mean, that would be really useful.” (P3024)

Those who reported changes in their perceptions towards critical thinking suggested that they developed more awareness about critical thinking following the intervention. These participants also suggested that they would be more conscious of inappropriate language use in arguments in the future to avoid committing a fallacy. This feedback suggests that students find that the intervention equips them with valuable skills which extend beyond the learning content of the intervention, and which enhance their overall decision-making and evaluative capabilities.

“I think that I’ll be more aware of critical thinking now that I’ve done the study, because when I’m looking at lectures now, I will remember to be more critical, especially like, when I’m writing my essays.” (P3002)

“I’m aware of those fallacies and I feel more confident that I won’t just because I’m quite naive, in general, so I feel like I’m more able now to you know, if someone says something, if I read something that will be similar to one of those fallacies, I will be able to spot it. Yeah, to spot them when I listen to someone or to just be careful to not make that mistake myself.” (P3020)

A subset of the participants also indicated that the intervention had caused them to reassess their critical thinking abilities, which they had previously overestimated.

“I thought I was quite comfortable. I realised that I wasn’t as comfortable as I thought.” (P3004)

“It helps, I guess, a little bit like so it makes me acknowledge where my critical thinking lies.” (P2020)

On the other hand, some other participants reported no improvements in their critical thinking abilities following the intervention or were not sure whether their critical thinking skills had improved. For example, Participant P3019 commented that more practice would be necessary before an improvement could be observed.

“I think, to be able to improve critical thinking, you still need some form of like, practice, like, it’s just like how lawyers need to, you know, they have to have this constant practice to, to have to be able to have these, like critical thinking skills embedded into themselves.” (P3019)

Another participant (P2024) highlighted that the efficacy of this intervention hinges upon the genuine motivation of students to actively engage and participate in the learning process in order to reap its benefits. This response suggests that the intervention works well for individuals who are already inclined to engage with the content, thereby underscoring the need for intrinsic motivation as a key factor in educational success. However, it also implies a potential limitation of the intervention for those who may require more external motivation or structured guidance.

“I think it’s a pretty useful way of learning. I guess it assumes that the learner is self motivated and self driven, and wants to learn about the topic. So I think it’s a useful model, if the person is someone who likes to learn, or has something specific in mind that they want to learn.” (P2024)

In conclusion, the intervention was generally well-received by the participants who reported that it enhanced their knowledge and their perceptions regarding critical thinking. The majority of participants agreed that the intervention effectively taught the skill of identifying fallacies, which was considered highly relevant to both academic studies and daily life. These findings suggest that a brief video-based intervention could be an effective

way to support the development of critical thinking skills in higher education. Nevertheless, the intervention does not solely lead to improvement, it also involves reassessment and acknowledgement of the complexity of critical thinking, where participants might realise that their abilities might not have improved or may still be uncertain about their progress in critical thinking.

Theme 2: Effective video design and presentation

The second main theme found consisted of two sub-themes: “*3 minutes is optimal!*” and “*Mixed opinions towards the need for an instructor*”.

Participants expressed a strong preference towards video-based learning and indicated that they would prefer information to be presented in an engaging video, rather than in text. These participants also suggested that videos made it easier for them to engage in learning as they reduced the number of texts presented.

“I find it hard to read lots of text and take it all in. The videos are a lot better.”
(P1020)

“I definitely prefer the video. It was very attention-grabbing, you know, and very sort of informal, you know, very easy to just watch rather than being too texty. I’d prefer short read. So anything that’s text like I wouldn’t have been able to grasp as much.” (P3004)

“I prefer video. I think it’s kind of the information is easier to learn when it’s presented in a nice and interesting way.” (P3007)

The preference for video content over text points to the intervention’s alignment with contemporary learning preferences, where multimedia content can enhance engagement and comprehension. Although there was a strong general preference towards video instruction, an exploration of students’ preferences towards specific characteristics of the intervention revealed two themes with respect to the length of the video and the necessity of video instructors, which are relevant to designing an effective video learning session. These are discussed in the following sections.

3 minutes is optimal!

When participants were asked about their opinions towards the length of the videos presented, the majority of them indicated that the videos were of an optimal length of 3 minutes.

“I don’t really like really long videos. But at the same time, I don’t like videos that are really short too either. So that’s the middle way. I think these videos were kind of in the middle. there not too short, not too long. There are three minutes I think they went into enough depth to understand the point to understand and but not too long that I would get bored.” (P3016)

“I thought it was a very good length. I mean, it was very, you know, short, but also informative, which meant that you had 100% of my concentration at all times, because it wasn't so long.” (P3008)

Participants' preference towards brief and engaging videos highlights the potential of visually appealing audiovisual materials to capture attention and improve learning outcomes by catering to participants' cognitive and attentional capacities. Some participants also provided feedback about specific design elements of the videos, such as the time spent per concept.

“I think the length is also fine. I think three minutes is not too small, not too large. And I think 45 seconds per concept is a good average. So I think that's fine.” (P3001)

However, a smaller number of participants provided specific suggestions for improving the learning material. These suggestions were related to the amount of information presented on screen and the pace of the video presentation.

“I think the video worked really well, my reading speed for some of it because it is written in quite dense. Not that for the first bit but as it goes on, you end up with a lot of text being presented at the same time. On the video screen, I found it a little bit challenging, and I would have liked a little bit longer to read.” (P2004)
“The video was okay. I did it struggled to read as fast. So the way that the time that it was coming on reading now, I wasn't, it was moving on to the next part before I'd finished reading the slides.” (P3004)

Mixed opinions towards the need for an instructor

In response to a question about the potential presence of an instructor in the videos, some participants expressed that they were satisfied with the current design that did not include a video instructor. These participants further suggested that having a video instructor might be too distracting or limit the versatility of the learning materials. The preference for visual aids over a talking instructor indicates that participants might benefit more from clear, visual representation of information rather than split attention between visual and auditory inputs.

“It's nice and simple as it is. If you put somebody else in there, it's kind of takes away from it because now you pay attention to that person and not necessarily taking it all in because some people prefer to have pictures.” (P2009)

The ability to control the pacing of their learning experience is also highlighted by another participant as a significant advantage of the current video format. The participant's preference for pausing and rereading content underscores the importance of self-paced learning in accommodating individual learning needs and styles. An instructor's

continuous narration could disrupt this flexibility, making it harder for learners to digest and revisit specific pieces of information at their own pace:

“I like the whole thought of, I could pause it out, you know, when the frame would finish sort of telling me the information, I could always pause it and reread it. So I mean, I think in that regard, having an instructor would make it difficult because, you know, you wouldn’t be able to, to pause it without having to then go back to find out what the instructor was saying beforehand.” (P3008)

However, some other participants reported they would prefer the involvement of an instructor in the videos. This group of participants appeared to believe that an instructor’s voiceover might help make the learning videos more engaging and improve learners’ understanding and knowledge retention. Some of these accounts made a reference to the concept of a preferred learning method and the availability of a visual and an auditory channel in their learning:

“I think personally yes for an instructor’s voiceover. For my learning method, I tend to like, you know, the visual aspect you’ve got it but like, I would do a lot better if there was like audio like a voiceover explaining either experience or just like, you know, repeating what was being written out. I think it registers a lot better for me.” (P2018)

According to another account, the voiceover would be useful because it could give participants a pace in navigating through the learning content. A voiceover could provide a change of pace and break the monotony, thereby enhancing engagement and preventing cognitive fatigue.

“If there’s a voiceover, then it might improve it further. Because even in the video, you are looking at the text. But if there’s a voiceover then like, it will be a better change of pace. And I think it’ll prevent people from getting bored or zoning out. So I think yeah, I think like, a voiceover might be better in that aspect.” (P3001)

In general, participants held positive attitudes towards video-based instruction. Nearly all participants expressed a preference for short videos of about 3 minutes, though some felt that the pace of these videos could be improved. With regard to instructors in the videos, their opinions were mixed. Those who wanted an instructor referred to the benefits of auditory-visual integration in video presentations.

Theme 3: Valuing of technology-enhanced learning

The third main theme that emerged from the analysis was the “*Valuing of technology-enhanced learning model*”, consisting of two sub-themes: “*Multiple benefits of technology-enhanced learning*” and “*Varied applications of bite-sized videos in teaching*”.

Multiple benefits of technology-enhanced learning

Previous research has suggested that a technology-enhanced learning model, such as video learning, is a versatile tool effectively utilised to support various pedagogical strategies within the higher education setting (Zainuddin & Halili, 2016). This educational approach enables educators to enhance their curriculum with supplementary materials that facilitate the acquisition of knowledge and the development of practical skills outside of traditional face-to-face sessions (Carmichael et al., 2018).

In the current study, most participants suggested that technology-enhanced learning models, including intertwined videos and online practice elements, have the potential to enhance learning. Some participants commented that intertwining videos with practice questions make learning more interactive when videos are intertwined with practice questions.

“It was really good, like a really good learning thing and it was a lot more enjoyable than the other studies I’ve taken part in because I feel like although you’re learning, it becomes more interactive, when you have to do watch a video and then do some test related to that video. So it becomes more interactive.”
(P1020)

“I enjoyed the video, you know, the video that was in the middle. Because that obviously, it gives you all the information, which then worked with the multiple-choice questions, so that element of it, I found really interested” (P2009)

This feedback highlights the engaging and interactive nature of the intervention. By combining videos with practice questions, the learning process becomes more active and enjoyable, which can enhance retention and understanding of the material. Participant P2002 also highlighted that they believed that technology-enhanced learning could be as effective as in-person teaching:

“I don’t think that it would be any less helpful than a teacher in-person teaching these constructs, like, I think that the video is sufficient for educating me about these things. The video is in conjunction with the practice, of course.”

This participant’s confidence in the effectiveness of video-based learning suggests that well-designed educational videos can serve as a viable alternative to traditional in-person instruction. This finding is significant, particularly in the context of the increasing reliance on online learning environments. Furthermore, Participant P2024 indicated that technology-enhanced learning would be particularly effective for self-directed learners:

“I think it’s a pretty useful way of learning. I guess it assumes that the learner is self-motivated and self-driven, and wants to learn about the topic. So I think it’s a useful model if the person is someone who likes to learn, or has something specific in mind that they want to learn, and they can just search it up and have the course and just apply for the course.”

Technology-enhanced learning was particularly relevant to the current climate in higher education that is shifting towards blended or online learning environments following the COVID-19 crisis. Responses from the following participants captured these:

“With the current situation and blended learning and everything. It obviously could potentially benefit students because they watch a video and they learn more. Like obviously, we have classes online classes, but I feel like videos could really benefit, especially these videos were like shortened to the point I thought it was really good. And then, you can practice like watch a video and then practice, like I did in the study.” (P2005)

“Yeah. Especially I will say with COVID. And the fact that we’re probably like, no one’s going back to 100% face to face teaching at the moment or anytime foreseeable future. I definitely like throughout the last year, the module that we just had videos, basically slideshows, and recorded without any speech over direct link type stuff. I think I probably did better in those than the ones where we have like actual, like online lectures, if that made any sense.” (P3022)

Varied applications of bite-sized videos in teaching

During the interviews, students also offered insights into the areas of teaching where video-based learning would be valuable. A notable percentage of participants acknowledged the potential of video technologies to increase engagement in traditional lecture settings when used as supplementary teaching tools.

“I think having, you know, a video here and all that will actually sort of make the lectures a bit more interesting. Maybe even actually used at the end of the thing to sort of say, you know, to conclude what the entire PowerPoint is about maybe, you know, three to five minutes’ video would actually be perfect.” (P3008)

“So if you teach some courses, maybe sometimes use like video illustrations, maybe from YouTube or something, it really makes the student really understand what everything means. It’s easier than just telling them some information.” (P3011)

This feedback suggests that short videos can effectively complement traditional lectures by providing summaries or visual reinforcements of key concepts. This approach can enhance student engagement and help consolidate learning, making lectures more dynamic and interactive. A few of them also commented that videos like this would be particularly helpful for reviewing and revising material, especially for subjects that are perceived to be more challenging.

“I think that would be good for like a revision video because it’s quick. It’s like, it gets to the points of everything.” (P3003)

“I think for things like research methods and investigative psychology [first-year statistics module], I think that they could do with stuff like that a lot more because they’re a bit harder to wrap your head around. Whereas I think the videos make it more simplistic, and you know what you’re doing a bit more” (P1020)

Other participants suggested that these video-based learning sessions would be beneficial for introducing new topics to novice learners as they present information in a more engaging way. Engaging videos can capture students’ attention and interest, making them an effective tool for introducing new topics. This method can help establish a solid foundation of understanding, upon which more detailed information can be built.

“I think it would be useful to have like a video like that, that’s quite engaging and interesting to look at, at the beginning of it with like, explaining each concept and stuff, cuz I find myself paying more attention to it than if it’s like, you know, somebody just spitting this information out.” (P2001)

“I think there’s a lot of potential with these sorts of video resources, because they help in disseminating information in a much friendlier way. To every person, it doesn’t even have to be kind of within academia or anything like that, but just kind of any person. It’s just, you know, it’s proven to be a lot more easier to learn, if you’re engaging with the content, and it’s interesting for you.” (P3007)

In general, participants acknowledged the potential of technology-enhanced learning to support in-person teaching and learning activities, especially in the post-COVID-19 era. Additionally, bite-sized video lessons were identified as valuable resources that could be developed into supplementary teaching aids for introductory courses and revision purposes.

Theme 4: Divergent experiences derived from the practice phase

The fourth main theme was “*Divergent experiences derived from the practice phase*”. In this study, we explored students’ learning experiences when they were exposed to a specific practice phase. That is, a self-directed learning control group, a PT intervention group that received a timed-based frequency-building practice aiming to increase the rate of fallacy identification, and a PT+ intervention group that received an untimed problem-based training in addition to the timed-based frequency-building practice.

These divergent experiences could be attributed to two key factors: their perceptions of Speed \neq Accuracy in timed-based practice and their perceptions of problem-based training as good for transfer training.

Speed \neq Accuracy

Both experimental groups (PT & PT+) received practice guided by a high response-rate requirement implemented in iterations of timed sprints and feedback. Within the practice session, 20 multiple-choice items were presented. Each item comprised either an example

or a definition of a fallacy, and was followed by four choices prompting participants to identify the corresponding fallacy. Participants from the experimental groups were instructed to answer the questions as accurately and as fast as they could within a minute. The timed practice element of the intervention aimed to improve fluency (i.e., both accuracy and speed) in fallacy identification for desirable outcomes, and, in line with the theoretical underpinnings of PT (Kubina & Yurich, 2012), enhance knowledge retention and application. Consistent with this idea, participants who received this timed-based practice recognised the value of it and enjoyed the challenge of performing under time pressure:

“I really enjoyed this part...I think I’m a bit of a competitive person. So that’s why I really enjoy it, like I really needed to answer the question.” (P3011)

“I did enjoy having like em...like having time sessions. Just think that it put me under pressure, and I think I perform better under pressure.” (P3016)

However, it appeared that even though some participants shared the view that the timed practice was helpful, there were concerns that the time factor might have impacted their performance in the task. This participant’s feedback highlights the dual-edged nature of timed practice. On one hand, the rapid pace can induce a sense of being rushed, potentially compromising the thoroughness of responses. On the other hand, the time pressure may foster quicker recognition of logical fallacies through repeated exposure and practice:

“Personally, I feel like it was a little bit like quick and rushed. Like, I’d have to answer 20 questions in a minute, which like, doesn’t leave me a lot of time to read each statement and think about it properly. Well then, I guess in some ways, it helps me to like, recognize certain arguments faster as I do more tests and as the time goes by.” (P3019)

Another participant also acknowledges that while the time limit may induce errors due to haste, it also trains them to recognize fallacies more swiftly and intuitively. This suggests that timed practice can serve as a valuable tool for developing quick cognitive responses, despite potential initial inaccuracies:

“I thought that some of the times the errors I made were because I was going too fast, because I was trying to answer them as fast as possible, the time limit. But I think I see the value of the one-minute time limit because it forces you to try and just recognize them more quickly and more intuitively. I think that if I didn’t have the time limit, I would have read the example slower, and might have been a little bit more accurate with my responses, but I don’t think it had a massive impact.” (P2002)

Good for transfer training

With regard to structured problem-based training, some comments suggested that it facilitated the adaptation of skills into a real-world context, noting its effectiveness in bridging the gap between theoretical knowledge and practical application. Specifically, Participant 2001 and 2017 indicated that this type of practice was necessary as it created an important connection between this new knowledge to their existing knowledge or a familiar real-world context.

“That (problem-based) practice was really well like really nice. And I think that was one of the parts that I also enjoyed a lot because it was more I felt like it was easier to be honest for me to relate logical fallacies to it because it was scientific articles mostly. So because like we are used to, at least I’m used to like in like academia, to like see these articles, and to like fight and look for these problems and stuff...And it was relatively like, easy for me to do it.” (P2001)

“So the one that helped me the most to, to understand all these concepts better is through the problem-based argument as the second bit that you mentioned” (P2017)

These comments suggested that the structured problem-based training may serve as a platform for transfer training. However, if this is to be included as a key component in the technology-enhanced intervention, participants’ discussion suggested that this may be more effective if the clarity of instructions and questions were improved.

“I wasn’t sure exactly what was expected from me because I was supposed to be an expert in some field. And then like, was I supposed to advocate for something or was supposed to point out where the judgments were, you know, false, for any reason. So I think that’s the part I enjoyed the least.” (P2015)

“I thought some of the things it wasn’t very, I wouldn’t say it wasn’t very clear, just the answer didn’t jump out at me. You know, I wasn’t sure whether it could be one or the other, because I felt like there was not enough information given in the context. I found myself kind of repeating what the question said, which was how I’m very used to writing scientific ways.” (P2018)

Participants’ difficulty in discerning the correct responses indicates that the problem scenarios might require more detailed context or background information. Providing sufficient context is essential in problem-based training to ensure that learners can apply their knowledge effectively and derive accurate conclusions.

Discussion and conclusions

Although critical thinking is a key objective of higher education (Hatcher, 2011), it remains a challenge for higher education to support students in building this essential skill for the

modern workplace (Abrami et al., 2015; Zhao et al., 2016). Moreover, there is a lack of effective instructional strategies for promoting critical thinking in online learning environments (Guiller et al., 2008; Richardson & Ice, 2010), while little is known regarding students' attitudes and perceptions of tuition methods for critical thinking.

The current study aimed to offer insights into students' views towards a technology-enhanced learning intervention for critical thinking skills among university students. The intervention, which was based on teaching informal fallacies through bite-size videos and precision-teaching-based practice, successfully enhanced skill acquisition and retention. In this study, we were interested in students' experiences and perceptions of the usefulness of this intervention, its potential to support mainstream provision, and their preferences regarding specific elements related to the presentation of learning materials.

Our findings suggested that, overall, students had a positive experience using this intervention, with many of them indicating that the intervention successfully taught them a new skill in identifying fallacies. Some students also reported improved awareness and attitudes towards critical thinking following their engagement with this intervention. These results are important as critical thinking is well-reported as a concept that many students find hard to grasp and often confuse with a focus on criticisms or weaknesses of a particular theory (Duro et al., 2013; Harrington et al., 2006). Positive outcomes of this intervention were also reflected in students' opinions towards its relevance, with many of them expressing that the intervention was helpful and highly applicable to their academic studies and daily life.

Regarding the presentation of learning materials, some students we interviewed had a strong preference for video-based learning. These students alluded to the benefits of video technologies in presenting information in a more engaging and simple way. This finding is consistent with previous literature that suggested video technologies are well-received by students due to their flexibility and versatility to accommodate students with diverse needs (Salina et al., 2012; Tan et al., 2023a; Tan et al., 2023b). Our results also reflected a student preference towards bite-sized videos of 3 minutes or less. This result was in line with past evidence suggesting that shorter videos could improve viewers' attention and reduce the possibility of cognitive overload (Brame, 2016; Carmichael et al., 2018; Khong & Kabilan, 2022). Bite-sized videos like the ones used in this intervention focus on presenting information in a manageable amount and have been found beneficial in maximising engagement and improving knowledge retention (Brame, 2016).

The preference for 3-minute videos among students might stem from their recognition that shorter segments offer information in easily digestible portions, potentially influenced by the application of the coherence principle in our video development (Mayer & Fiorella, 2014). The coherence principle focuses on seamlessly integrating visuals and on-screen text to optimize learning outcomes. In our videos, animated visual demonstrations were

paired with concise textual explanations, both presented concurrently on-screen. This deliberate adherence aimed to alleviate cognitive overload and enhance information retention by establishing a direct correspondence between visual elements and textual explanations. Nevertheless, this inclination warrants a more profound exploration into the reasons behind students' perception of the 3-minute optimal video length. Further investigation should consider how varying levels of content density, audience cognitive abilities, and the utilisation of multimedia components impact the perceived effectiveness of video duration.

Regarding students' views towards the potential involvement of a video instructor, their opinions were divided. Some students, who preferred the current design without a video instructor, commented that the presence of an instructor might divert their attention away and affect the versatility of the learning materials. This account presents similarities with the cognitive load theory, which suggests that additional stimuli may distract students' attention away from content and hinder learning, especially when the content contains complex information (Carmichael et al., 2018; Wang et al., 2017). On the other hand, other students, who preferred the presence of an instructor, said that voiceover aids engagement and knowledge recall. This account is similar to the dual-processing theory, which posits that using visual and auditory channels to present information enhances engagement as our working memory has limited capacity (Mayer & Moreno, 1998). The use of dual modalities in presenting information could facilitate the selection and organisation of information across channels to form a 'mental model' that is suitable to be stored in long-term memory (Clark & Mayer, 2016).

Regarding students' opinions towards the potential of the technology-enhanced learning approach to support mainstream provision, more than two-thirds of students expressed a positive view towards this possibility. These findings chime with previously reported accounts suggesting that technology-enhanced learning offers effective teaching and learning experiences (FitzGerald et al., 2018). Students also shared some valuable and diverse examples of how video-based learning design could complement learning, in line with past research suggesting that video technologies could enrich mainstream provisions with supplementary materials that can support ubiquitous learning (Syed et al., 2020). These examples also demonstrate that video-based education offers a versatile and flexible approach that supports individualised learning needs and preferences (Salina et al., 2012).

With regard to students' views towards the learning tasks, not all students gave positive remarks towards the timed-based practice. While it was intended to improve fluency in fallacy identification, some students found it challenging to perform better under time pressure. However, some other students enjoyed this type of training and said it was beneficial for recognising faulty arguments faster. A similar mixed account was offered for the structured problem-based training, whereby some students showed an appreciation to

the training to bridge the gaps between concepts and practice, while the rest thought that in moving forward, the clarity of the training needs to be improved.

The enjoyment experienced by students engaging in timed-based practice might be attributable to the integration of game-based learning elements within educational settings. This aligns with motivational and engagement theories in learning. Elements like timer countdowns, immediate feedback mechanisms, and scoring systems simulate aspects of game-based learning, known to heighten motivation and engagement (Juhari et al., 2020). Students might find these activities enjoyable due to their immersive nature and the challenges they present. Moreover, the varied perspectives regarding the effectiveness of structured problem-based training could possibly be explained by Haring and Eaton's Hierarchy of Learning (1978), which outlines stages of learning such as acquisition, fluency, retention, generalisation, and adaptation. Students tend to find tasks enjoyable when they feel proficient in performing them and when they perceive a clear connection between the acquired skills and their real-world applications. In our study, the structured problem-based training garnered appreciation from some students as it effectively bridged the gap between theoretical concepts and their practical implementation, aligning with the 'fluency' and 'generalisation' stages of the learning hierarchy.

The incidence analysis carried out under the pragmatist approach adopted in this study has also provided additional practical insights into students' experiences and perceptions of a technology-enhanced learning intervention for critical thinking development. Firstly, more than two-thirds of participating students (67%, 20/30) found the integration of bite-sized videos and practice in web-based sessions to be an effective educational tool for improving their critical thinking skills. A significant percentage of students (43%, 13/30) also perceived the technology-enhanced learning model as versatile and has great potential for use in various educational contexts. Secondly, our findings showed that whilst the majority of students (77%, 23/30) prefer bite-sized videos of less than 3 minutes as they improve engagement, some students commented that the pace (17%, 4/23) and instructor presence (37%, 11/30) are critical factors in video design and presentation to facilitate efficient learning. Thirdly, the timed-based practice was experienced in various ways, with some enjoying having the challenge of performing under time pressure (37%, 11/30), while others did not (47%, 14/30). Finally, some students (30%, 9/30) contended that problem-based learning tasks have their benefit in facilitating knowledge transfer in critical thinking instruction, but the clarity of tasks could be improved to maximise its impacts.

This study is also particularly relevant to recent changes in the higher education landscape following the COVID-19 pandemic. This is as limitations in contact time are especially important for teaching critical thinking. The intervention addresses this challenge by promoting the independent learning of critical thinking skills outside of formal teaching sessions (Mandernach, 2006) and based on bite-sized video-based learning

in an online learning environment. This technology-enhanced model with video-based learning was perceived by students as a powerful and versatile approach, offering students the opportunity to pause, rewind, and revisit any part of the information whenever needed (Salina et al., 2012).

Limitations

This study is not without limitations. One important limitation refers to the validity of the interview process. This could have been enhanced with an additional researcher being involved in the data collection and coding processes. However, this was not possible due to the limitations in funding and resources.

In terms of research design, the current study focused on the overall students' experience using this intervention. However, there was no specific measure of students' learning experiences in relation to the practice conditions that they received (i.e., self-directed control, PT intervention, or PT+). Through the interviews with participants from both the experimental and control groups, we delved into their experiences during the practice phase. The responses from the control group outlined a practice session structure that involved watching a video and repeating tasks, while the experimental group emphasised features such as timed trials and problem-based training. The structural differences in their practice methodologies make it challenging to directly compare or correlate the experiences and outcomes of both groups within our study.

Future studies could look into the differences in learning experiences between practice conditions as well as between low-performing and high-performing students, especially when the former showed higher gains in critical thinking skills in the quantitative study (Tan et al., 2022; Tan et al., 2023c).

Conclusion

In conclusion, this study provides insights into the experience of students, the key stakeholders, from using a technology-enhanced learning intervention to support the development of critical thinking skills. Overall, students expressed favourable experiences from an online intervention that involved bite-sized video learning elements. Our findings have clear implications for future efforts of higher education institutions to foster critical thinking, one of the most valued skills in the labour market. There are also broader implications of our findings for the development of online learning interventions. For example, from a practical perspective, student preferences towards video design and presentation, such as the video length and instructor presence, may inform methods to engage students best and facilitate optimal learning (Carmichael et al., 2018).

Abbreviations

PT: Precision Teaching; WHO: World Health Organization.

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Authors' contributions

Tan, A. J. Y. designed the study, performed data collection, and wrote the original manuscript with support and guidance from all the other authors. Kaye, L., Davies, J. and Nicolson, R. provided feedback to analyse the data as well as contributed to the review and revision of the final manuscript. Karaminis, T. supervised the work as well as contributed to the planning, discussion of the results and the final manuscript. All authors read and approved the manuscript.

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Availability of data and materials

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations**Competing interests**

The authors declare that they have no competing interests.

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