Student active learning in a digital classroom: high-performing science students' perceptions of their experiences

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ABSTRACT: In March 2020 higher education institutions across Norway closed campuses in response to the COVID-19 pandemic. This study explored five high-performing science students' perceptions of their experiences with active learning in a digital physiology classroom. A thematic analysis explored the detailed first-person subjective experiences of learning in the digital classroom to add to the knowledge base about how science students can be supported to learn physiology in remote and digital learning contexts. Five superordinate themes central to the students' experience were identified: 'accountability and self-regulation', 'building strategy and structure', 'creating community and social learning', 'difficulty and discomfort essential' and 'efforts to reframe adversity'. The students recognised the importance of self-regulation, structure, social interactions, and challenge, explaining how aspects of the course helped or hindered their learning. Differential responses to the use of peer-evaluation and the ability of high-performing students to reframe adversity were evident. Active learning approaches in the digital classroom supported science students in gaining a deeper understanding of physiology.

1 AIM AND PROBLEM

The COVID-19 pandemic raised challenges for higher education around the world as courses previously taught on campus were suddenly required to be taught online. The rapid development of educational countermeasures presented opportunities and limitations for educators at all levels. On March 12th, 2020, when University campuses around Norway were closed, a class of science students had just begun an introductory physiology course and were among those whose learning experience was moved to the digital classroom.

This study sought to explore the experiences of some of those students to add to the knowledge base about how science students can be supported to learn physiology in remote and digital learning contexts. The aim of the study was to investigate how students experienced and responded to active learning in a digital physiology classroom. The study explored whether the students' perception of their experience of learning online was consistent with the notion that active learning is crucial for increasing understanding of physiology and explored approaches to achieve this in digital learning environments.

2 SCHOLARLY CONTEXTUALISATION

Active learning has emerged as a prominent evidence-based best-practice in science education (Freeman et al. 2014; Goodman, 2018; Michael, 2006; Hake, 1998). Active learning approaches vary in both intensity and implementation, including activities such as group problem-solving, worksheets, use of response systems, peer instruction, tutorials, and workshops. The commonality in these approaches is a shift away from traditional "teaching by telling" lecturing. The American Physiological Society have "recognized the need to advocate for inquiry-based and student-centred curricula as essential to effective science instruction" (Stieben, Pressley & Matyas, 2021). Effective science instruction risked being interrupted by the COVID-19 pandemic. Studies reported declining student engagement amongst both STEM (Wester et al. 2021) and non-STEM (Perets et al. 2020) undergraduates taking STEM courses during COVID-19-driven remote learning.

Sandrone and colleagues (2021) are amongst those who have argued that the challenges raised by the COVID-19 pandemic presented an ideal opportunity to "transform educational delivery" and embrace active learning as the basis of STEM education, "rather than replicate the educational modus operandi in an online form." In addition to the learning advantages of active approaches, Sandrone and colleagues highlight the key role collective learning plays in promoting core *community of practice* (Wenger, 1998) characteristics, such as sense of belonging. In remote learning situations it may be particularly important

to adopt learning approaches that foster community, to improve students' learning experience, engagement, and sense of belonging.

An international survey of 4,789 undergraduate students' experiences and perceptions of remote learning methods during the COVID-19 pandemic suggests that students missed the social aspects of learning on campus and that most students prefer synchronous online classes (Nguyen et al. 2021). Since students were recruited to this survey via Instagram, the respondents were presumably active users of the social media platform, and as such the findings from this survey may potentially overemphasize the positive aspects of online social interaction. Nevertheless, Nguyen and colleagues found that "students whose synchronous classes include active-learning techniques report significantly higher levels of engagement, motivation, enjoyment, and satisfaction with instruction" and go on to conclude that "active-learning methods, which are known to increase motivation, engagement, and learning in traditional classrooms, also have a positive impact in the remote-learning environment."

Despite evidence-based enthusiasm for using active learning approaches to enhance student experience in remote and digital learning contexts, selecting and integrating teaching tools into these settings can be daunting. Surveys may fail to capture nuanced information about how students experience these approaches and how they can be supported to learn in these settings. To further explore how active and student-centred learning activities may be experienced by students taking remote and digital science courses, the current study explores science students' perceptions of their learning experience during a student active physiology course, forced online by the COVID-19 pandemic.

3 METHOD

3.1 Overview

A range of active digital approaches, including group discussion, problem-solving tasks, projects to create digital products and use of digital audience response tools (Banks, 2006) such as (Mentimeter AB, Stockholm, Sweden), kahoot (Kahoot! Oslo, Norway), quizlet (Quizlet Inc. San Francisco, USA) and socrative (Showbie Inc., Edmonton, Canada), as well as digital teaching methods more closely resembling traditional teaching methods in higher education, such as pre-recorded video lectures, were used during an introductory physiology course at a higher education institution.

The course made use of spaced repetition (Smolen, Zhang & Byrne, 2016) by having a few pre-recorded video lectures split into 15-minute videos recorded using Prezi video (Prezi Inc, Budapest, Hungary) or Screencast-O-Matic (Screencast-O-Matic, Seattle, USA), followed by seminars using active learning approaches to repeat topics covered in the lectures, or to delve deeper into these topics. Seminars were held using ZOOM (Zoom Video Communications, Inc. San Jose, USA). ZOOM's break-out rooms function was used to facilitate problem-solving tasks, group discussion tasks and group projects to create digital products, whereas activities using digital response tools were carried out in the main ZOOM room, with ongoing guidance, explanation, feedback, and clarification from the teacher. When using break-out rooms, randomly organized groups of 3-4 students were used. The teacher circulated through all break-out rooms at regular intervals. While working on group projects to create digital products, students maintained the same groups across multiple sessions.

Summative assessment was by digital oral examination with an external sensor. All 22 students who took the course were invited to participate in an anonymous digital course evaluation survey (no digital footprint) in SurveyMonkey (SurveyMonkey, California, USA). 16 students completed the course evaluation survey. Interview participants were recruited at the beginning of the following semester, taking part in one semi-structured interview about three months after the final exam. The anonymous responses from the course evaluation survey, teacher observation reflection log as well as student comments, via multiple communication channels during the course informed development of the interview guide and form part of the qualitative dataset.

3.2 Participants and data collection

Following approval from the Norwegian Centre for Research Data, students were recruited to participate in interviews. Students invited to participate had completed the introductory physiology course in the Spring 2020 semester and were still studying at the higher education institution at the beginning of the Autumn 2020 semester. Of 16 eligible students, five science students (three male; two female)

volunteered to be interviewed. At the time the teaching took place they were first-year (2) or second year (3) students. Written informed consent was provided prior to interview. Verbal consent was recorded. All five interview participants had achieved A (excellent) or B (very good) grades in the final summative assessment of the physiology course and had high levels of attendance in the synchronous online teaching sessions (ZOOM seminars) during the course. On these grounds, the five interview participants have been defined as high-performing students.

Participants were interviewed on university premises. An interview guide was developed. Questions were asked verbatim to all participants, with additional follow-up questions used when appropriate. Interviews were conducted in Norwegian, audio recorded and transcribed verbatim. Topics included the students' overall experience of learning in a digital classroom in Spring 2020, their experiences with using the online learning platform (Canvas Learning Management System, Instructure, Salt Lake City, USA), peer-evaluation of student assignments, asynchronous video lectures, synchronous ZOOM seminars, their experiences with group activities using breakout rooms and with digital response tools such as mentimeter, kahoot, quizlet and socrative.

The impact of an existing professional teaching relationship between the lead interviewer and interviewees was considered during data analysis through the researcher's reflective notes.

3.3 Data analysis

Thematic analysis is a useful and flexible data analysis method for identifying, analysing, and reporting themes within qualitative data (Braun & Clarke, 2006). In the current study, thematic analysis was used to explore the individual participant's personal perceptions or retelling of their experiences of learning physiology in a digital classroom. The nature of any human experience is that how it is experienced and retold depends on the individual's first-person perspective, and where their attention is directed both during the experience itself and upon recounting that experience. The participants' verbal accounts are also a reflection of the students' efforts to make sense of their experiences. The terms attention and consciousness, and the relationship between them is a subject of controversy (Pitts, 2018). Throughout this paper the term experience is intended to encompass the full extent of the students' subjective lived experience. This definition assumes that both 'attention-dependent conscious perception' and 'perceptual awareness' may contribute to students' experience.

Thematic analysis recognizes that the research process is dynamic. Access to the participant's perspective is both dependent on, and complicated by, the researcher's active involvement. The researcher learns about the participant's experience through an interpretative process, whereby the researcher identifies patterns and themes, selects which are of interest, and reports them to the readers (Braun & Clarke, 2006) also referred to as double hermeneutic (Reid, 2005; Smith et al. 2003).

Data were analysed, in accordance with a thematic analysis methodology, first using NVivo 12 (Pro 12.6.0.959 64-bit edition; QSR International 2019, Melbourne, Australia) to perform an initial broad sweep of the data to observe in vivo codes, and to begin to recognise patterns and emergent categories and themes. Interview transcripts were read and re-read with ideas and insights generated and noted. Emerging codes, categories, patterns, and themes were generated in English from the Norwegian interview transcripts. Semantic content and language use were considered, including with respect to accent, grammar, syntax, and vocabulary use in the individual participants' dialects. Connections across themes were identified. Once all accounts had been read and analysed several times, patterns across accounts were investigated. Superordinate themes and sub themes were created that captured the shared experiences of the participants. Attention was given to understanding the differential experiences of the participants on topics where accounts of their experiences differed substantially. Interview excerpts used in this article have been translate into English. The author is a native English speaker and professionally fluent in Norwegian, including familiarity with the informants' dialects.

4 FINDINGS

Five superordinate themes were identified, bringing together the data from the five participants. All five themes were clearly identified in all five transcripts. However, not all sub themes were evident in all five transcripts and differential responses to, and recollections of different teaching methods were observed. This insight contributed towards the superordinate and sub themes. For example, the

differential responses to being asked to give peer-evaluation is included as part of theme three: creating community and social learning.

4.1 Theme One: Accountability and self-regulation

This theme explores how the participants perceive the role that their own accountability and self-regulation played in their experiences of active learning in the digital classroom. This theme also pertains to how the teacher might support students' accountability and self-regulation through aspects of course design in remote and digital learning contexts.

Sub themes

- Personal accountability and responsibility
- Independence and self-reliance
- Role of self-awareness
- Availability and flexibility as a blessing and a curse

Although the students had different study habits and attitudes, there was a commonality expressed by participants linked to the increased importance of accountability and how aspects of course design can both help and hinder their efforts to self-regulate their learning activities. Some of the students reported that personal traits had helped them respond to and handle the increased demands of learning in the digital classroom, compared to on-campus learning.

"I am quite a structured person who can sit down and do things without it having to happen at a particular time."

Other students reported being less self-disciplined, commenting that when the campus closed, they had purposively chosen study strategies that they felt they would be able to stick with, indicating a role for self-awareness in regulating learning activities.

Some students expressed the perception that elements of the course design contributed positively or negatively to their ability to self-regulate their remote studies. When asked about the seminars, one student commented that because of the nature of the activities they were asked to participate in on ZOOM *"it is almost a prerequisite that you have read a little"* before class.

When asked about the individual and group projects, where students were asked to make short videos or presentations one student expressed that this increased the perceived experience of accountability: *"I make more demands on myself if I feel I have to perform for someone else afterwards, and that was part of it, with the digital products."*

However, some aspects of the course were perceived as a hindrance to student accountability. When asked about the asynchronous video lectures one student commented that *"it is easier to drop them than it is the zoom classes, there is no obligation to attend."* The ZOOM sessions were not mandatory, attendance varied from 40-70%. However, it appears that this student experienced an increased sense of obligation to attend synchronous ZOOM seminars as they were timetabled, scheduled events.

Most of the students appreciated the availability and flexibility of the video lectures.

"If there were things that were demanding then you could go back to the video and watch again and watch it as many times as you like."

"I really liked that lots of course content was available all the time, it did not matter what time of day you worked."

The participants perceived that learning in a digital classroom placed increased demands on them to take responsibility for their own learning, compared to learning on campus. The students' ability to self-regulate played a key role in their experiences of learning in the digital classroom and was both helped and hindered by aspects of the course design.

4.2 Theme two: Building strategy and structure

This theme explores the impact that the teacher can have by building a clear strategy and structure into the online course design and making this clearly visible to the students. The importance of structure as it relates to the digital learning platform was very clear in the accounts of all five students.

Sub themes

- Well-organised courses help with organising thoughts
- Clear course structure makes studying more time-efficient
- Importance of consistency with headings and sub-headings
- Utilising spaced repetition

One student connected the organisation of the course within the digital learning platform to a perception of time efficiency, whilst another connected the digital organisation of the course to their ability to organise their thoughts.

"Personally, I really like things to be structured because then I can easily organize my thoughts."

Several of the students indicated that a poorly organised learning platform can cause frustration, even when the teaching is primarily on campus.

"I think it's important all the time! ... It was important then and is important now and will be important in all subjects."

Despite overwhelming agreement about the importance of clear and systematic organisation of the digital learning platform, the students expressed that the online course representation is something separate from the actual teaching and learning. One student remarked that Canvas is: *"very central, it is our main learning platform, where information from lecturers goes out to students… I look at it a bit like the car you use to get to work, you almost do not arrive without a means of transport."*

One student underlined the importance of consistency with the use of headings and sub-headings in the lecture notes and videos, something they had found challenging in topics such as the immune system, where the Norwegian equivalents of terms such as adaptive, acquired, or specific immunity are used interchangeably.

Another recurring sub-theme related to course structure was the benefit of utilising spaced repetition, whereby topics from video lectures were repeated in seminars and core concepts in physiology such as flow-down gradients, structure-function connections and information flow were highlighted in several topics. When asked about their experience with the ZOOM seminars one student commented: *"I notice that I learn a lot more when I get to repeat things and then you are a bit forced to repeat it, yes, good experiences with the seminars, combined with the video lectures."*

The students' accounts reflect an increased demand in remote and digital learning contexts that the user interface should be clear enough to allow intuitive navigation, without ongoing guidance. Although such clarity is always desirable, with in-person learning, the user interface is augmented by the teacher's physical presence and capacity for ongoing clarification of course structure.

4.3 Theme three: Creating community and social learning.

This theme explores how the students recognise the importance of the social element to learning and how having a relationship and dialogue with the teacher and other students impacts their learning experience.

Sub themes

- Smaller groups, more involvement and discussion
- Importance of facilitating student-student interaction
- Opportunities for working together towards a goal
- Discussion aimed at reaching common understanding of phenomena

Before we look closer at elements of course design students perceived as helping to create community and social learning in a digital classroom, it is important to underline that this is the most significant element that the students perceived was lost when the campus closed. When discussing the advantages and disadvantages of different digital teaching approaches one of the students stopped and remarked *"you have to see it in the right light, physical teaching is many times better".* Statements like this are supported by the findings of a large survey (n>2200) of student experience conducted by the university in May 2020 (Christiansen, 2020). What the students wanted most was to return to in-person teaching.

The students expressed that break-out rooms in ZOOM were one of the best aspects of their experience of learning in a digital classroom. During the course, students used break-out rooms in small groups for a variety of discussion tasks including a group project assessing the reliability of online sources of nutritional information, to debate ethical dilemmas in biotechnology and to practice explaining to each other how action potentials are generated in neurons. One student described it like this:

"There was not so much of the lecturer talking to us through the screen, we had an opportunity to communicate with each other. That I would say was the best part about zoom, break-out rooms."

Several of the students explained that the perceived threshold for participating in discussions is lowered because of the smaller group size in break-out rooms compared to in the main zoom room.

«My experiences from these break-out rooms, I think it was a little easier to be able to comment and say my opinion and hear others' opinions in a smaller group."

While several students, particularly those who expressed that they had been starved of social contact during this time, highlighted their positive experience with break-out rooms, students also experienced that utilizing digital response tools in the main ZOOM room added value related to being able to see what other students thought.

"It was quite interesting to see what others thought, you can see, oh here are some who think it can be true, why? It gives a little food for thought and when you get to participate then you become a little more active, when one is active, one feels one learns a little more."

Students perceived benefits of being assigned group tasks where they discussed a phenomenon, reached a common understanding and shared that by making short videos or presentations for the other students.

"Quite often, there can be some misunderstandings of what you read. Then you can sit and discuss back and forth, again, what do you think is important, OK, we must include this."

The use of peer-evaluation in the digital classroom was experienced differentially by the students. There are many ways peer-evaluation can be given, it can be oral or written, anonymous or non-anonymous, in-the-moment or with time to reflect and formulate feedback. The students described, in their verbal accounts, advantages and disadvantages of these different approaches. Some students acknowledged that they could learn from being given the opportunity to see, and reflect upon their peers' work, as intended by the teacher. Some students found giving feedback to other students uncomfortable, even when the peer evaluation was anonymous. There was no clear answer from these students on how they perceive peer-evaluation contributes to learning outcomes. Some students do not see any value in peer-evaluation as a learning activity.

Two contrasting excerpts from the interview transcripts illustrate the differential experiences with peer-evaluation that the students relayed.

"You can probably learn a little if you just look at the work, but if you are going to assess it then you probably reflect a little deeper and think about what is good and what is bad. What would I do? ... So, one probably learns a lot, by doing peer-assessment."

"I think peer-assessment was a bit uncomfortable because you want to be as factual as possible, but then you are afraid that it might affect the relationship you have with these people that you are going to meet every day and study with."

Most of the students found that giving peer evaluation digitally was different than giving it in-person and some recognised that there can be positive and negative aspects to this difference.

"If it's face to face, if they do not understand your reasoning then you can explain again immediately, if you are going to write a message to each other than it takes much longer to clarify the misunderstandings ... but at the same time you have plenty of time to formulate... saying it orally right away you say maybe the first thing you think about, and do not think so carefully about how the other person perceives what you say. You get more time to formulate yourself the way you want then."

4.4 Theme four: Difficulty and discomfort essential

This theme explores which aspects of active learning in the digital classroom the students perceived as contributing the most to increasing their understanding of physiology.

Sub themes

- Stimulating thought processes
- Resistance to and embracing discomfort
- Difficulty as a path to curiosity
- Ambiguous and reflective tasks deepen understanding
- A process for identifying and clearing-up misunderstandings

Evident in all accounts was the importance of challenge, difficulty and ambiguous questions which required thought, time, reflection, and discussion to solve or explain. To deepen understanding, students perceived the need to be given a task that they did not immediately understand and could not immediately answer and had to spend time thinking about. Examples of this from the course, which were mentioned explicitly in the students' accounts and seem to have had a lasting impact on the students included the longer crime investigation task aimed at understanding cellular respiration by solving a murder mystery, and response tasks in ZOOM. Typical response tasks in ZOOM involved statements being presented via mentimeter that the students were asked to evaluate the veracity of, either by giving a binary true or false response or by responding to the degree of veracity on a sliding scale. A feature of mentimeter is that everyone's answers can be made visible anonymously to the other participants and to the teacher, who can then pick out elements from the students' responses for further discussion or explanation.

The crime investigation task was based on the Tylenol murders in Chicago in the 1980s, later developed into a teaching case study by Michaela Gazdik (Gazdik, 2010) and adapted into the Norwegian context and language for this course.

The many questions that students were challenged with in mentimeter included:

- Stig has type B blood and Lotte has type A blood, can Alf who has type O blood be their biological child?
- The saturation of oxyhaemoglobin decreases rapidly when climbing to altitudes above 2100 meters above sea level. How true or false is this statement?

The students explain at length how they experienced these types of tasks and how the difficulty and misunderstandings they experienced helped to further their understanding.

On the crime investigation about cellular respiration and the electron transport chain:

"It was set up as if it were a crime case. So, you kind of go in with a slightly different type of curiosity, a slightly different motivation, where you start looking at the task and do not understand anything, and then you have to read up on the process and maybe understand where in the context the error occurs so that the problem can be identified."

On being invited to respond to ambiguous questions in mentimeter:

"I think menti contributed a lot to understanding, at least of the things I had not understood already. There were some tasks that we did there, I remember, that I did not understand at all, and then we spent some time discussing what it was really about, and as soon as you start discussing things, then there are many questions and things get resolved. The questions that were perhaps a bit ambiguous where you can argue that it is both true and not true, then I feel that I learned a lot because it was not just that it is right or wrong, it can be both and then you must use argumentation and it goes a little further than just remembering things or understanding things."

A different student describes how they experienced responding to difficult questions presented with the response tool mentimeter in the ZOOM seminars.

"To be able to choose between different options you have to think, can this be right? And so, you justify yes or no and so on and start excluding some answer options and then end up with one that you should answer."

The findings presented above relate to the use of response tools in general and provide insight on how these tools were used in the current study. The students also appreciated benefits of using response tools in the digital classroom to address the issue of a perceived high threshold for speaking up and asking a

question in a main ZOOM-room. Here is an example of a student reflecting on how the teacher can use response tools in lieu of reading facial expressions and body language.

"Maybe the mentimeter can work a bit like reading facial expressions during a lecture. If there is something that seems unclear you can go a little deeper into it."

Several of the student accounts explicitly used this word deeper (*dypere*) when explaining how challenge and difficulty contributed to furthering their understanding.

4.5 Theme five: Efforts to reframe adversity.

This theme explores how this group of high-performing students recounted their efforts to handle the adversity of active learning in a digital classroom during the COVID-19 pandemic.

Sub themes

- No FOMO when you do not know what you are missing
- Looking on the bright side / noticing advantages
- Survival strategies
- Helping each other
- Accepting adversity

There are many examples in the students' verbal accounts, where the students, on recollecting their experiences, or recalling a perceived negative aspect, negative event, or disadvantage, quickly reframe this perceived adversity and say something positive about it. Even in the accounts of the students who use negatively loaded adjectives and describe negative affect the most frequently, we see examples of them looking on the bright side, mentioning survival strategies or extolling a degree of acceptance of the situation.

Rather than expressing that they experienced a fear of missing out (FOMO) due to the lack of laboratory practical classes, one student asserts that *"since I never had those lab classes, I do not really know what it was I missed so my experience is based on what we actually did."*

This is one of only two brief mentions of the lack of practical laboratory classes across all five transcripts. The students, however, are talking about and making sense of their experiences, not what they did not experience. They are being asked about how they experienced the teaching that was delivered, not what was not delivered. Therefore, this cannot be interpreted as a perception that practical laboratory classes are not important. Indeed, the second mention of the lack of practical work in the course, by a different student, is more rueful: *"it went pretty well, but I was expecting to have a little more between my fingers."*

Rather than dwelling on the adversity of not being able to meet classmates in person, another student flips this around adding that *"it is easier to meet because you can meet anywhere, and you are not dependent on meeting at school. So, I would say that is the advantage."* The students have not been asked to give perceived advantages and disadvantages, rather, this reframing of adversity seems to be a skill they have developed or a way of painting their experience in a more positive light in the retelling process. Although the existence of a professional teaching relationship with the lead interviewer may have influenced the students' accounts, this apparent habitual reframing of adversity and 'looking on the bright side' was very clear, and the students' accounts were otherwise balanced and credible, suggesting that this reframing ability may be a facet of how these high-performing students handled the pandemic.

One student painted a particularly idyllic picture of their study experience. *"Especially in the spring it was very nice weather so then I prioritized sitting outside in the sun and studied early in the morning or in the afternoon instead."*

As much as these high-performing students seem to make efforts to reframe perceived adversity, again it is important to place these observations in the correct light and underline that these measures were enforced due to a global pandemic. As one student puts it:

"I'm happy that teaching is being done digitally rather than my whole education being put on hold, it has not been optimal, but it has not been optimal for anyone, so it's just a situation we find ourselves in. Corona sucks, but we must live with it."

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5   DISCUSSION AND REFLECTION

The aim of this study was to understand the experiences and perceptions of science students in response to active learning in a digital physiology classroom during the COVID-19 pandemic. These findings contribute a qualitative analysis of such experiences based on detailed first-person accounts. The accounts of five high-performing students highlight five superordinate themes central to their experience. Whilst some of the insights provided are equally relevant to in-person learning environments, others are unique to remote and digital contexts.

Learning physiology in a digital classroom placed increased demands on these students to self-regulate their learning activities. The high-performing students described the role these increased demands for accountability and self-regulation played in their learning experience. The students' accounts indicated a perception that several competencies were involved, including self-discipline, time-management skills, and self-awareness. While some students believe that personal characteristics play a key role in their ability to self-regulate their learning, elements of the course design and structure also play a role and may be a help or hindrance. For example, scheduled classes may create a greater sense of obligation to attend, regardless of whether attendance is obligatory, active repetition opportunities can increase motivation to show up well-prepared and tasks which will be shown or performed to fellow students can contribute to an increased sense of accountability. Research suggests that students who can regulate their own learning use metacognition, motivation, self-awareness, and self-efficacy to monitor and modify their behaviour and develop strategies focused on reaching their desired learning outcome (Boekaerts, 2005; Harding, 2018; Pintrich, 2004; Zimmerman, 2002;). The experiences of students during the COVID-19 pandemic, supports the idea that students should be taught self-regulated learning strategies during their schooling (Harding, 2018). Interestingly, the high-performing students' accounts evidence an underlying perception that these skillsets and strategies are innate to who they are, rather than the result of acquired behaviours they have learnt or been taught.

Unsurprisingly, clear course organisation in the digital learning platform is perceived as an advantage to the students' learning experience regardless of whether the learning is primarily in a digital classroom or on campus. Students report mixed experiences with their digital learning platform, indicating that higher education institutions may need to allocate more resources to this factor.

The students recognised the importance of social elements to learning experiences and described different ways in which these were lost and maintained after the campus closed. Sociocultural learning theories (Bandura, 1977; Vygotsky, 1978) are student-centred and present insight into collaborative approaches to student learning. As higher education institutions require their educators to be pedagogically qualified, the use of collaborative, cooperative, inductive, and inquiry-rich teaching approaches may become even more prevalent. The current study further supports the idea that active learning approaches which promote community are particularly important in remote and digital contexts (Wenger, 1998; Nguyen et al. 2021; Sandrone et al. 2021).

The high-performing students' accounts suggest that some students experience discomfort associated with giving peer-evaluation. This finding may support the need for more training and guidance for giving and receiving feedback from peers, to prepare students for the demands of work and life. Iglesias Pérez and colleagues provide evidence that students perform well as peer evaluators and argue that self- and peer assessment have advantages for the training of responsible, critical, and reflective professionals (Iglesias Pérez et al. 2022). Given the discomfort reported, it remains unclear whether this was an appropriate arena for building additional psychological and social resilience on top of the demands of responding to the pandemic. However, the what is clear is that the experience of giving peer-assessment is different depending on the format of the feedback. If the goal is to train future professionals, perhaps students should practice giving and receiving peer-feedback in a variety of formats and settings.

The students interviewed in the current study describe their experience of a productive struggle towards understanding. For these high-performing students challenge was a path to curiosity. In the digital classroom, where the threshold for stimulating dialogue and discussion was higher than during in-person teaching, ambiguous, reflective questions functioned as a tool for stimulating discussion

which furthered the students understanding of physiology. The breadth of the course content was ambitious with respect to the course duration, and by introducing more challenging content there is a danger of students being left behind. However, without introducing difficulty, there is a risk that students' curiosity and understanding will not be stimulated, physiology will be perceived as merely a collection of facts to be memorized and physiology's core concepts, and range of applications will not be discovered or appreciated. Ideally, science students will gain an appreciation for core concepts and connections as they learn and ultimately be able to connect physical, chemical and biological phenomena to everyday observations and experiences. These ambitious goals affect the way we teach.

The high-performing students' verbal accounts revealed habits of reframing adversity and actively pursuing optimism as they made sense of their experience of digital learning. This finding aligns with a study of student persistence in UK higher education, which found that key drivers of students' perseverance are "personal optimism, academic engagement, and positive relationships" and that "successful student persistence tends to be a result of an intricate interaction between the student's personal factors and their environment" (Gabi & Sharpe, 2019). When teaching was suddenly and unexpectedly moved to the digital classroom the learning environment that teachers were able to create from their home-offices played a key role in the students' experience.

Educational countermeasures to the COVID-19 pandemic greatly impacted several aspects of students' experience of learning physiology. The physical learning space and the experience of closeness, remoteness, structure, and chaos was impacted as well as the students' physical connection to the subject through the lack of practical laboratory classes. An obvious weakness of the current study is that the recruitment process self-selected for highly self-regulated high-performing students whose accounts did not fully capture the sensory deprivation and adversity we have observed amongst students who struggled the most during the pandemic. Perhaps most importantly the students' experience of human relationships and interaction and learning from each other's questions and answers was impacted. Attempts to curtail the impact of these losses, the use of break-out rooms and digital response tools, were appreciated but could not fully compensate for the lack of a rich, integrated, social learning experience in the digital classroom, when compared to campus life.

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