

How, Where, And When Do Students Experience Meaningful Learning?

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Abstract

Meaningful learning occurs when learners actively connect new information to prior knowledge, leading to benefits in engagement and knowledge retention and transfer. Consequently, STEM courses increasingly seek to employ such practices in their programs. Currently, little is known about students' beliefs regarding the value of meaningful learning and which formats promote it. However, insight into the student perspective is essential to effectively (re)design courses to support this type of learning. We surveyed a large cohort of biosciences students (N = 321) to determine which class formats (lectures, workshops, practicals) and delivery modes (online, face-to-face) they believe maximise opportunities for meaningful learning. Likert scale questions and inductive thematic analysis of open-ended questions showed students believe meaningful learning is most likely during in-person workshop or practical sessions, mainly through knowledge application, problem solving, and interaction with peers and educators. By contrast, students view inadequate opportunities to check understanding, lack of engagement or challenge, and difficulty interacting with peers and educators as barriers to meaningful learning. These findings provide a framework for educators to increase opportunities for students to engage in meaningful learning in their courses.

Introduction

Given the growing importance of student evaluations in determining the quality of teaching (Kinnunen et al., 2018), data on our undergraduates' expectations and experience have never been more relevant. New undergraduates also hold preferences regarding the class and assessment formats that they will receive at university (Sander, Stevenson, King, & Coates, 2000). Such preferences vary by cultural context and can be explained through socialisation (Larkin, 2010), such as prior experiences in secondary education. Although there is considerable literature on the individual learning style preferences (Kolb, 2007; Williams, Birch, & Hancock, 2012), relatively little is known about students' beliefs about the effectiveness of these formats when viewed strictly from a meaningful learning perspective.

Meaningful learning is described as the interaction between a student's past knowledge and the new information they are attempting to learn (Cadorin, Bagnasco, Tolotti, Pagnucci, & Sasso, 2016). This interaction paves the way for new enduring knowledge to be created that is built on top of, or in addition to, existing knowledge structures. This definition of meaningful learning aligns with a constructivist perspective of learning and dates back to the 1960s (Ausubel, 1963; Mayer, 2002; Howland, Jonassen, & Marra, 2013). According to Ausubel (1963), meaningful learning involves students interpreting their cognitive experiences, rather than simply recovering

the information. In the constructivist approach, the primary pedagogical objective is to work towards transforming the learner's existing knowledge (Cadorin et al., 2016).

The utility of meaningful learning interventions is relatively well established, ranging from increased conceptual understanding of physics concepts in pre-service teachers (Demirbas, 2014) to improved clinical reasoning in nursing students (Dreifuerst, 2012). Interventions to promote meaningful learning vary considerably but often involve students working collaboratively to construct knowledge together (Rozenszayn & Ben-Zvi Assaraf, 2011). Students can also independently engage in meaningful learning using an active retrieval approach (Karpicke, 2012). Tasks that require the learner to engage in higher order thinking also promote meaningful learning (Bijsterbosch, van der Schee, & Kuiper, 2017).

Are student beliefs on what comprises meaningful learning in line with current conceptions from educational research? Studies indicate that senior high-school students have a conception of learning that values rote acquisition of facts relatively heavily (Brown, 2002; Lin, Lee, & Tsai, 2014). If such beliefs inform student preferences with respect to class formats, delivery modes, and assessment formats, this would conflict with current practices at teaching universities, which tend to favour constructivist approaches, though this may not always be the case in practice. Moreover, student perceptions of the quality of the education they receive at universities, and thus the feedback they provide in student experience surveys, depend on agreement between these two perspectives, and there are indeed reasons to believe this is not always the case. The use of flipped learning, for example, where directly instructed content is taught asynchronously using video resources, has increased in recent years (Karabulut-Ilgu, Jaramillo Cherez, & Jahren, 2018). Yet, the student perspective on flipped models to effect meaningful learning are not consistently positive (Hao, 2016, Korucu-Kis, 2022). Prospective students also hold relatively favourable views of lectures (Sander et al., 2000, Kugler, Gogineni, & Garavalia, 2019) despite the ongoing debate in the pedagogical community about the value of the lecture (French & Kennedy, 2017). Indeed, teacher-guided learning methods such as the lecture have been shown to be associated with students' cognitive involvement and learning achievement, compared to student-directed methods now used at universities (Fischer & Hänze, 2019). Awareness of such discrepancies between students and educator perspectives on what constitutes meaningful learning should allow educators to improve their educational approach and justify it to their students.

To gain greater insight into the motivations behind student preferences, here we present the result of a mixed-methods study where we investigate student perspectives on the value of different class formats and delivery modes, strictly based on their role in promoting meaningful learning. We surveyed broadly across students enrolled in undergraduate and postgraduate biosciences courses at a major university of Melbourne, Australia. For the purpose of the survey, meaningful learning was defined as "learning that allows the learner to connect new information to their prior knowledge, to develop a comprehensive understanding of the material, and that motivates the learner to want to learn." We asked students whether they valued meaningful learning and to nominate their most and least preferred formats (lectures, workshop/tutorials, and practical sessions) and delivery modes (online or on campus) from this perspective. We also solicited justifications for their choices in open-ended questions for qualitative analysis and prompted students with different potential strengths of these class formats using Likert-scale agreement scores.

Methods

Survey audience

Our survey was distributed as an online questionnaire developed in the Qualtrics Platform. The voluntary survey was introduced in twelve subjects by teaching staff not involved in the research, yielding three-hundred twenty-one responses from students enrolled in one or more biosciences subjects in semester one, 2022. Two-hundred seventy of these students were first-year students, with the majority being enrolled in the bachelor of biomedicine (~70%, with a 30% response rate in this cohort). Thirty-nine of the students were in second to fourth year and 12 were postgraduate students.

Statistical analysis

Statistical analysis was conducted in R. Analysis of numbers of student responses was conducted with log-linear models using the built-in *glm* function. Non-significant interactions were omitted from final models. Much like χ^2 analyses, log-linear models analyse the number of responses and, therefore, are typically used to look at associations between variables, (i.e. interactions), not individual variables (i.e. main effects). Analysis of Likert responses was conducted with ordinal regression models using the function *polr* from the *MASS* package with significance testing using the *Anova* function from the *car* package. Both log-linear and ordinal regression models produce odds ratios to quantify the effect of any significant predictors. Within the thematic analysis, Krippendorff's α intercoder reliability (ICR) was assessed using the function *test_irc* from the package *tidycomm*.

Results

When asked whether they valued meaningful learning in an open-ended question, all responding students indicated that they did (N=143, data not shown - 83% of respondents were first-year students). Qualitative analysis of the responses as to why they valued meaningful learning yielded four themes (Table 1).

Table 1. Summary of thematic analysis for why students value meaningful learning

Themes	Student's comments
Allows development and consolidation of knowledge, application to new contexts	Being able to undergo meaningful learning will enrich your understanding and allow you to apply it in other areas. It is important to properly understand the content learnt, and to know how to use it in practical scenarios.

Efficient way to learn	Meaningful learning keeps my interest in what I'm learning and it increases the chance in which that knowledge could be retained in my memory. I value my time and want to be the most efficient learner possible.
Enhances motivation, engagement, and enjoyment.	Meaningful learning makes me feel more engaged in what I learn and provides a reason to why I learn the things I learn. It lets me find value in the content I am learning, realising that I am studying it for a purpose and increases my level of motivation.
Increased preparedness for future employment	Meaningful learning will prepare me for later research endeavours and potential career prospects in industry.

Preferences for class formats

We analysed students' perceptions of the class formats most and least conducive to meaningful learning with their language background and gender included ($n = 251$ and 260 , respectively; see Fig. 1; statistical results in supplementary materials). Respondents who nominated 'Other' as their gender were omitted due to low numbers of responses. In both analyses, language background and gender were significant, reflecting the fact that more native English speakers and females responded to the survey (Figure 1, supplementary materials Table 2). For workshops, the overall odds of being considered most conducive to meaningful learning were 70 percent greater practicals, whereas those for lectures were 67 percent less likely. Workshops and practicals were both less likely to be considered the least conducive with odds 76 and 69 percent less compared to lectures, respectively. Interestingly, there was an association between language background and format preferences: native English speakers' greater aversion to lectures compared to non-native speakers was evident in both datasets, whereas non-native speakers saw practicals as relatively less likely to lead to meaningful learning compared to native speakers (see supplementary materials Table 2). Gender showed no associations with class format or language background.

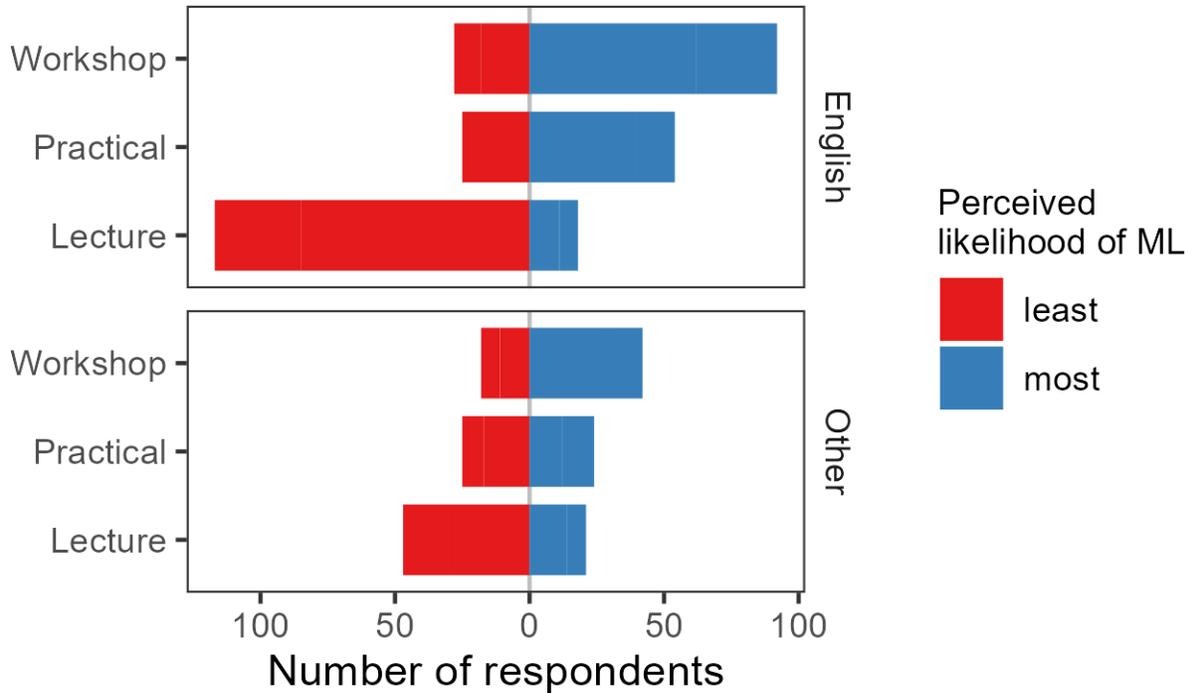


Figure 1. Distribution of student responses to the question “which class format (lecture, workshop, practical) was most and least conducive to meaningful learning”, split by the language background of the respondents (native speakers of English or other languages).

Components of preferred class formats

Each participant rated Likert statements based on the degree to which each contributed to meaningful learning for their chosen learning format. These statements were grouped into the broader categories (Fig. 2). The consistency among the statements that comprised each category, as measured by Cronbach’s alpha, was moderate (Table 1 of supplementary materials), indicating that they did not probe identical underlying latent variables.

Thematic analysis of students’ open-ended responses justifying their choice of class formats most- and least-conducive to meaningful learning identified a number of themes (Table 2 and Table 3, respectively).

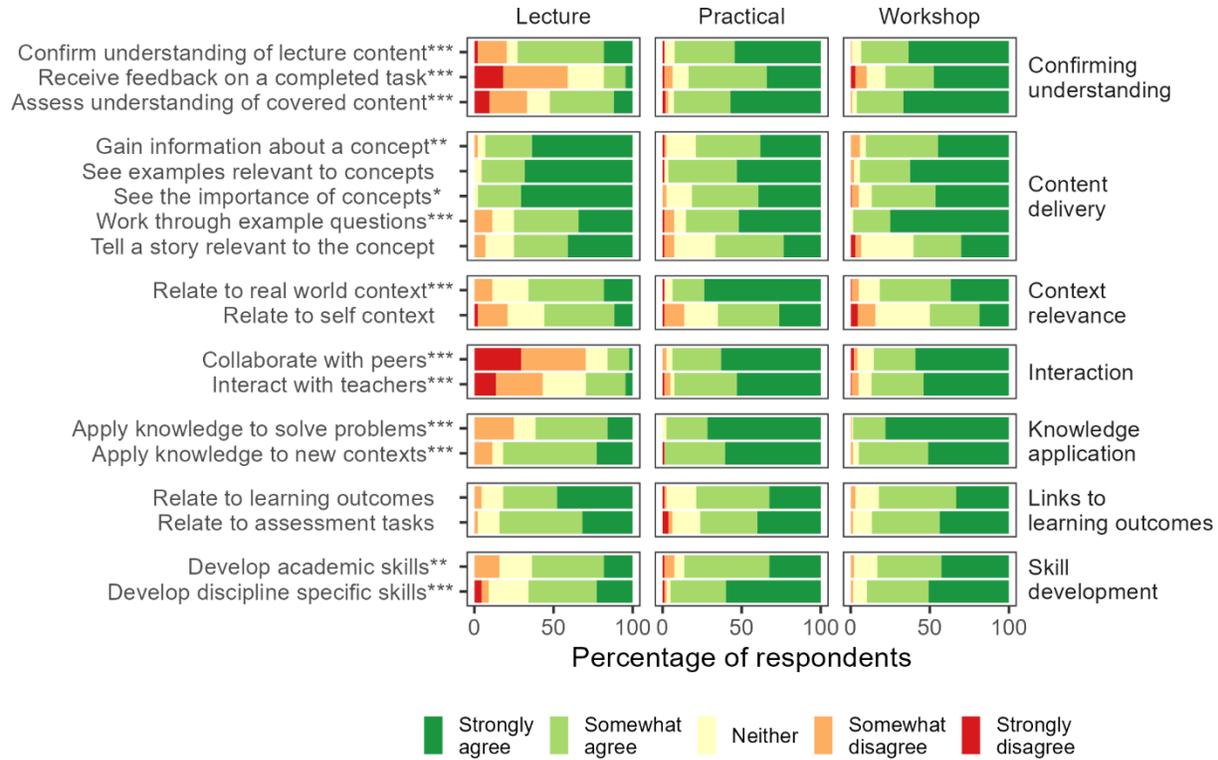


Figure 2. Distribution of student responses to Likert questions querying their agreement with a number of statements describing components of the learning experience that potentially contribute to meaningful learning. These statements were phrased as “... because I get to [statement]”. Statements have been shortened for graphing purposes. Asterisks refer to the significance of the effect of class format on Likert responses following logistic regression (*: $p < 0.05$; **: $p < 0.01$; * $p < 0.001$).**

Table 2. Summary of thematic analysis for likelihood of meaningful learning in various class formats

Class format	Themes	Student's comments
Workshop/ Tutorial	Active learning experiences through peer and educator interaction	Active engagement with people who you can talk to check your learning. We are talking to other students about the work and receiving different perspectives.
	Application of knowledge reveals real-world relevance	We are able to actually apply the knowledge for either problem solving or relate to real life issues.
	Opportunities to consolidate and deepen knowledge	Discussions with other people and hearing multiple points of views helps me think deeper about the topic in question.

Practical	Apply and build on existing knowledge Active and hands-on experiences with real-world relevance	You get to apply learned knowledge to a practical task, which requires problem solving and linkage of past information with new. You can link content learned to something with real life relevance, and generate an application for the content learned.
Lecture	Introduce new information relevant to the topics presented Recorded lectures facilitate self-directed learning	This is where new content and concepts are taught in vast detail. I have a time to pause and think at my pace, usually I will compare the old notes with the new ones and immediately search for my own questions.

Table 3. Summary of thematic analysis for least likelihood of meaningful learning in various class formats

Class format	Themes	Student's comments
Workshop/ Tutorial	Does not cater for individualised learning needs	Content given in the group setting attempts to match everyone's level when people are at different levels.
	Difficult to interact with educators and peers during workshops held in online environments, which hindered engagement	Difficult to communicate with students and collaboration was severely lacking.
	Exercises could be completed individually and did not always provide new information	There is a tendency to merely complete questions and discuss answers. I believe this can be completed in my own time.
Practical	Lack of challenge: largely procedural learning	I am using this time to do procedural learning rather than making the connection between the experiment and what I have learned.

	Can be stressful if there are many tasks to complete	Stressed because the work is quick, and I know I have to get through it to be assessed on the same day.
Lecture	Lack of opportunity to check understanding or connect to prior knowledge	It is just information being thrown at you, and therefore there is no real opportunity for active learning to occur.
	Difficult to engage due to information overload and lack of contextualization	It is a session in which students are bombarded with content without making it relatable or easier to understand other than just words and data.

Preferences for online vs in person sessions

We examined preferences for mode of delivery (online or in person) for each class format (lectures, workshops, or practicals) by asking: “Is a [format] more likely to be a meaningful learning experience when it is held on-campus or on Zoom?”. A clear pattern emerged from these data: for lectures, there was a small majority that saw online delivery as most conducive to meaningful learning whereas, for the workshops and practicals, there was an overwhelming preference for in-person delivery (odds ratios: 43.6 and 78.9 relative to lectures, respectively; Fig. 3, Supplementary materials Table 3). We did not detect an effect of gender on overall or format-specific mode preferences, but native speakers of a language other than English expressed considerably greater overall preferences for online delivery than native English speakers independent of class format (odds ratio: 5.40; Supplementary materials Table 3). We did not detect any three-way associations between mode preference, language background, and class format.

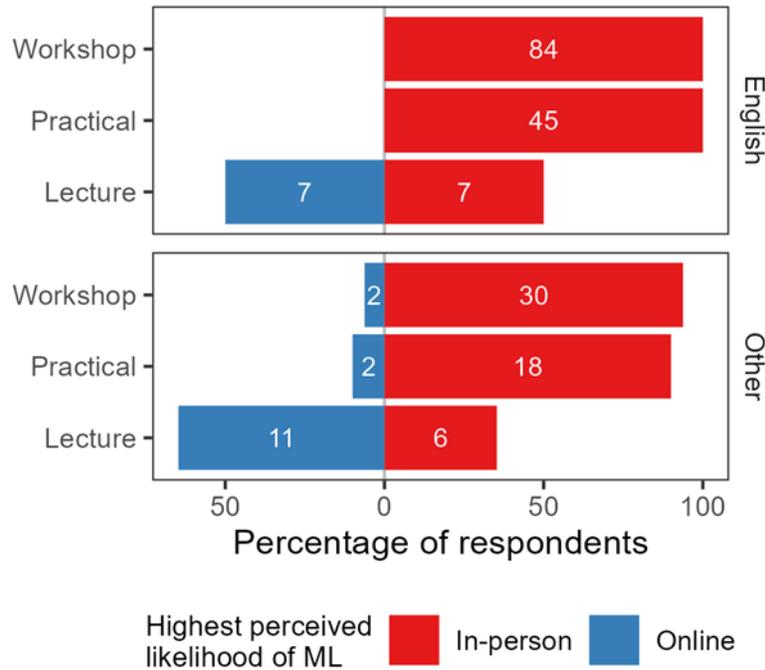


Figure 3. Distribution of student responses to the question which class format (lecture, workshop, practical) and mode of delivery (online or in-person) was most conducive to meaningful learning, by language background (native speakers of English or other languages). In-set numbers represent absolute numbers of responses.

Discussion

1. The value of meaningful learning

All of our respondents indicated they valued meaningful learning as defined in our survey. This was not a given: students vary considerably in their motivations to study. Whereas intrinsically motivated students are driven by a desire to learn more about the subject matter, develop skills, and develop a deep understanding, those with extrinsic motives, such as the pursuit of credentials for employment, are not driven by such interests, which may impact their approach to learning (Kember, Ho, & Hong, 2010; Byrne et al. 2012). However, it is worth noting that students can hold both intrinsic and extrinsic motivations towards learning simultaneously.

A prominent theme in the students' responses to why they value meaningful learning experiences was that it raises motivation and enjoyment (Table 1). This aligns well with previous findings that deep learning approaches are associated with greater satisfaction among students with their entire educational experience (Nelson Laird, Shoup, Kuh, & Schwarz, 2008). Nonetheless, it may well be that activities designed to promote meaningful learning, by incorporating student-centric, active, authentic, or collaborative aspects, indeed were inherently more rewarding to students.

Other themes as to why students valued meaningful learning suggest that they saw it as an efficient way to develop and retain knowledge that can be applied in other contexts (Table 1). This indicates some metacognitive insights, since deep learning approaches indeed tend to increase long-term

retention (Marton & Säljö, 1976). This also opens up opportunities for the students to challenge their own understanding of the content by reasoning, evaluating and thinking critically.

2. Learning format suitability for meaningful learning

2.1. Lectures

Most students (63%) selected lecture as the format where meaningful learning was least likely to occur. Even those who believed it was the most conducive format for meaningful learning (17%) still rated its components lower than students with other learning format preferences, apart from some of those relating to content delivery. This finding was echoed in the open responses, which suggested that lectures are seen as primarily useful sources of new information about topics of interest (Fig. 2, Table 3). While the traditional lecture format may seem antithetical to the student-centred and deep approaches synonymous with meaningful learning, this may in fact reflect diversity in preferred learning styles. Learners who qualify as ‘assimilators’ in Kolb’s classification or ‘A’ in the VARK classification may be more inclined towards lectures for this reason (Wehrwein, Lujan, & DiCarlo, 2007). Although ‘assimilators’ are thought to be more common among males, we found no support for gender differences among preferred class formats. Recent work further questions the utility of such learning style instruments in curriculum design (Deng, Benckendorff, & Gao, 2022). We detected a reduced aversion to lectures among non-native speakers of English. This could be an artifact of their greater reluctance towards formats that require a greater oral participation (Ferris & Tagg, 1996), especially when lecture recordings are available (see discussion on delivery mode below), or caused by the greater reliance on traditional lecture formats in the home countries of our non-native English speaking students (Abeysekera, 2008). Finally, under the restrictions imposed by the COVID-19 pandemic, which our cohort experienced, lectures may hold some advantages over the other class formats (further discussed in the learning mode section).

The value of the lecture in modern-day higher education remains a divisive and hotly debated issue (French & Kennedy, 2017). The question as to the pedagogical value and desirability of the large in-person lecture has become particularly pertinent following its translation into pre-recorded video formats or live online synchronous delivery during the COVID-19 pandemic (Ross & McKie, 2021). Our results suggest that, in comparison with workshops and practicals, lectures indeed rate poorly in facilitating meaningful learning, particularly in the areas of interaction with peers and instructors, confirming understanding, and receiving feedback. Opportunities to interrogate and reason with new information are essential to reconcile and integrate it as new concepts within pre-existing knowledge structures (Ausubel, Novak, & Hanesian, 1968). This process can be further enhanced through collaboration where students share their knowledge conceptions and build a deeper understanding together and solve problems (Tenenbaum, Winstone, Leman, & Avery, 2020). Such activities force learners to think about the new material, analyse and synthesise it, which increases their engagement in the session (Freeman et al, 2014).

Our open and Likert responses suggest students believe lectures lack sufficient opportunities to confirm understanding, make connections with prior knowledge, and to interact with peers or educators, (Fig. 2, Table 3). In isolation, the traditional conception of the lecture in higher education, where an educator merely transmits information, is generally viewed as pedagogically incomplete (French & Kennedy, 2017). In accordance, the themes identified in this study confirm that students recognise the lecture as a useful initial exposure to new information but lack in

opportunities to actively engage. Nonetheless, much of the debate around the value of the lecture has considered the lecture in isolation rather than as fulfilling a necessary role within a mix of class formats that does include such opportunities, as in our study. The relative unpopularity of the lecture in our results could indicate that this realisation may also be lacking in the student body. If so, this would suggest that instructors should clearly communicate the rationale for the delivery strategy and function of each format to shape student expectations. Alternatively, lecture content can be delivered in more interactive formats that do include opportunities to actively engage, which may increase achievement and motivation but can come at the expense of the amount of content delivered (Huggins & Satmatel, 2015; Alaagib, Musa, & Saeed, 2019).

2.2. Workshops

Our responses indicated that students value workshops and tutorials as they provide the opportunities to interact with peers and educators, apply knowledge by solving problems with real-world relevance, and consolidate and deepen their knowledge. Although it may be expected that students would hold preferences for active learning formats such as workshops and tutorials, this does not always bear out. Surveys across disciplines showed that ‘interactive lectures’ were strongly preferred over ‘tutorials’ or ‘student-centred teaching’ among students commencing their undergraduate studies (Sander et al., 2000). In contrast, our cohort had at least several months experience in the university environment, which tends to alter student beliefs and attitudes (Redish, Saul, & Steinberg, 1998). Our results identified that students view the ability to apply, consolidate, and deepen their knowledge of the lecture content during workshops as contributing to meaningful learning. Learning through application is a key idea underpinning approaches such as problem-based learning (Hmelo-Silver, 2004) and the ability to transfer knowledge is a diagnostic of meaningful learning (Mayer, 2002). Students also cited the opportunities to interact with peers and educators as contributors, which aligns with findings elsewhere (Tenenbaum et al. 2020). The benefits of interactions with instructors are multifaceted, comprising both supportive and affective dimensions (Hagenauer & Volet, 2014). In particular, our respondents highlighted the importance of seeing instructors work through example questions or activities as an important contributor to meaningful learning.

While a minority of the students chose the workshop as the learning format in which they were least likely to engage in meaningful learning, some students believed that the workshop did not cater for individual learner needs. Greater instructional differentiation to cater to individual learner needs can raise student satisfaction but does impose time costs and remains relatively uncommon at the undergraduate level (Ernst & Ernst, 2005). Other criticisms of the workshop related to the group-work format: some students reported difficulty in working with peers that had different levels of understanding, whereas others suggested the exercises could be completed individually. Although this could argue for differentiation through ability grouping, this practice remains controversial and may in fact limit some of the benefits of diversity within groups. Other factors that limited interaction with peers and the educators, and hence the opportunity for meaningful learning, related to venues workshops were held in and the size of the classes. Like differentiation, the benefits of smaller classes and fit-for-purpose venues are well established (Kokkelenberg, Dillon, & Christy, 2008), yet often not implemented for economic reasons. As a minimum, it is imperative that learning environments are set up to promote collaboration between peers given the value students attach to this aspect of workshops. Finally, some comments addressed the fact that workshops do not introduce any new content. Students transitioning to higher education commonly lack an understanding of the intended function of the different class formats and workshops’ role

in consolidating and applying knowledge, highlighting a need to communicate this at the commencement of their studies.

2.3. Practical sessions

Almost one third of our respondents indicated that meaningful learning was most likely to occur in practical sessions. While this may appear a relatively modest proportion, it should be noted that part of the practical session experience for the first and second-year students within the surveyed cohort's was online, due to the impact of the COVID-19 pandemic. In spite of this, many saw the practical sessions as an opportunity to be active participants in a collaborative, hands-on experience that helped them see the real-world relevance of the content. Biology practicals, and science inquiry tasks more generally, are forms of experiential learning (Kolb, 1984): through active experimentation, students obtain concrete experiences that allow abstract conceptualisation following reflection. Meta-analysis shows that hands-on activities in science education considerably increase achievement (Caglak, 2017). A related theme in justifying the choice of practicals was the opportunity they offer to apply and build upon knowledge obtained elsewhere through problem solving in novel contexts. The ability to transfer obtained knowledge accordingly is indeed a key diagnostic for meaningful learning (Mayer, 2002). Lastly, students rated practical sessions highly in developing discipline specific skills as a means of meaningful learning. This is in line with a wealth of research showing that the acquisition of process skills and the use of authentic materials and equipment have strong motivational and achievement benefits (Hiçde & Aktamış, 2022).

While only 19% of students identified a practical session as the format where they were least likely to engage in meaningful learning, their justifications did highlight some of the challenges with this learning format. Some students viewed practical activities as largely procedural and hence lacking in challenge. Inquiry- and discovery-based pedagogies allow students significant independence to construct the intended meanings, while approaches more on the expository side of the spectrum provide a greater degree of pre-exposure to underlying theory and scaffolding (Weaver, Russell, & Wink, 2008; Bruck & Towns., 2009).

Another theme was that practical sessions were seen as stressful due to the number of tasks they comprised and assessment associated with the session (Table 4). Diversity in ability and motivation affect time management and productivity and, if not addressed, for some students much of the potential meaningful learning from these sessions will be lost. Consequently, to maximise meaningful learning in practical sessions, and to do so equitably, our data suggest the instructional approach and degree of guidance provided to students must match their capacity for autonomous learning, while providing differentiation to attend to individual variation. Unfortunately, the latter remains underutilised in undergraduate science laboratories, particularly in larger cohorts.

3. Learning mode suitability for meaningful learning

Given the more (inter)active and collaborative nature of workshops and practical investigations when compared to lectures, we hypothesised that students would express a stronger preference to experience these formats in person to maximise meaningful learning. Our results supported this idea: students commonly cited greater peer and teacher interaction. In contrast, a small majority of students considered lectures more meaningful when delivered as asynchronous online videos. Online delivery by no means precludes meaningful learning. Improvements in technology and the rapid shift towards online teaching during the COVID-19 pandemic greatly accelerated the

development of effective online learning environments and curricula (Dhawan, 2020). Indeed, asynchronous elements such as pre-recorded lectures in a flipped learning context provide opportunities for students to exercise self-regulation and autonomy (Fructuoso, Albó, & Beardsley, 2022). In accordance with this, studies have shown that students who report high self-efficacy in online learning prefer this mode and look back at their most recent online learning experience with greater satisfaction (Artino, 2010; Paetch & Schlosser, 2022). Selection bias among those who nominated lectures as their preferred learning format for meaningful learning towards students who possess greater learning self-efficacy provides a compelling explanation for our findings. Thematic analysis indicated that students consider pre-recorded lectures efficient due to the flexibility and convenience they offer. In particular, meaningful learning was enhanced by the ability to pause and rewatch lectures, which facilitated improved note taking. Additionally, students valued the knowledge consolidation exercises that typically accompany lectures in the learning management system to confirm their understanding. These themes align well with findings elsewhere (Barak, Hussein-Farraj, & Dori, 2016).

In practice, communication in synchronous online sessions via Zoom imposes significant limitations. Collaboration is a cornerstone of meaningful learning (Howland et al., 2013), yet difficulty in communicating with peers while attempting small group activities where students routinely had their cameras and microphones turned off was a common lament in our responses. In contrast, in justifying their preference for on-campus classes, students cited the ease in communicating with each other and their instructors. This difference was also evident in engagement: online sessions left more room for distraction. There is evidence that the low engagement and interaction students commonly experience in Zoom sessions, results in feelings of isolation (Serhan, 2020). ‘Zoom fatigue’ is now understood to be a multidimensional cause of disengagement and non-participation in online learning (Bailenson, 2021), indicating its prevention should be a key target in teaching and curriculum design to ensure meaningful learning in online teaching. Finally, our results echo a commonly cited limitation of online learning: the inability to teach practical skills (e.g. Mukhtar, Javed, Arooj, & Sethi, 2020). Hands-on practical activities such as experiments in science are highly conducive to meaningful learning since they, properly implemented, represent intentional (goal-directed), active learning processes with an elevated degree of authenticity. While some of these aspects can be achieved online through simulations, remote laboratories, etc. (Tho & Yeung, 2018), our students expressed a near-unanimous preference for the on-campus mode for practicals.

Conclusion

In this study, we aimed to examine the student experience by determining whether they value meaningful learning and, if so, to determine what delivery format(s) and mode they perceive to be most conducive to its occurrence. Our results indicate that students overwhelmingly value meaningful learning but also indicate they recognise elements in each class format (lectures, workshops, and practical sessions) that facilitate meaningful learning. However, striking differences are apparent in how students view these formats, both in their overall conduciveness and how well they lend themselves to online delivery. Students believed that in-person workshops or practical sessions were most likely to promote meaningful learning, as they provided opportunities for interaction with peers and educators, application of knowledge and problem solving. Whereas we detected no associations between gender and preferred class formats or

modes of delivery, our results do indicate that native speakers of languages other than English are distinct in those terms and should be considered in curriculum design to increase meaningful learning. Barriers to meaningful learning identified included a lack of engagement, difficulty in facilitating peer and educator interaction, and a lack of opportunities to confirm understanding. When combined with sound educational pedagogy, the insights presented in this study provide a blueprint for educators to engage students in rich meaningful learning experiences.

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Supplementary Materials

Table 1. Raw Cronbach's alpha scores representing the internal consistency of the Likert statement comprising the broader categories recognised in this study.

Category of statements	Raw Cronbach's alpha		
	Lectures	Workshops	Practicals
Knowledge application	0.64	0.64	0.66
Interaction	0.81	0.44	0.61
Content delivery	0.23	0.61	0.56
Confirming understanding	0.62	0.68	0.68
Skill development	0.77	0.52	0.70
Context relevance	0.63	0.64	0.59
Links to learning outcomes	0.75	0.68	0.65

Table 2. Log-linear modelling (analysis of deviance) results describing the effects of language background, class format, and gender on the number of responses when students were asked to nominate the class formats most and least likely to lead to meaningful learning. Non-significant interactions were eliminated from the final model. LR = Likelihood ratio.

	Most conducive to ML			Least conducive to ML		
	LR	Df	P	LR	Df	P
Language background	24.007	1	< 0.001	25.019	1	< 0.001
Class format	55.751	2	< 0.001	95.917	2	< 0.001
Gender	29.362	1	< 0.001	31.808	1	< 0.001
Language : class format	7.181	2	0.028	8.031	2	0.018

Table 3. Log-linear modelling (analysis of deviance) results describing the effects of language background, gender, class format, and mode preferences on the number of responses when students were asked which attendance mode was most conducive to meaningful learning for their nominated class format. Non-significant interactions were eliminated from the final model. A test for overdispersion was negative. LR = Likelihood ratio.

	LR	Df	P
Language	26.382	1	< 0.001
Mode	152.577	1	< 0.001
Class format	53.030	2	< 0.001
Gender	22.202	1	< 0.001
Mode × class format	61.083	2	< 0.001
Mode × language	13.174	1	< 0.001