



Challenging, Exciting, Impersonal, Nervous: Academic Experiences of Large Class Teaching within STEM

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ABSTRACT

Massification of Higher Education has resulted in a rapid increase in undergraduate populations, without an increase in the number of teaching staff. One consequence is that students are typically taught in larger classes. While the impact of class size on student satisfaction and attainment is debated, there has been little attention paid to the academic experience of large class teaching. We present results of a questionnaire completed by 80 academics, primarily based in the UK. Academics perceived classes of 100 or more as large, and most had taught classes of several hundred students. Academic perceptions of large class teaching varied considerably. We find no evidence that institution type or contract type affects perceptions of large class teaching. We also find a lack of training that specifically addresses the demands of large class teaching. We call on academic developers to support academics teaching large cohorts to ensure effective education at scale.

Keywords: teaching at scale, large classes, massification, academic development, higher education teaching

Introduction

Massification of higher education (HE) has fundamentally changed the experience of higher education for both students and academics (Hornsby & Osman, 2014). This expansion of HE has happened around the globe, and the pace of change has been high (Maringe & Sing, 2014). Ever larger numbers of students study at degree level or higher; 533,000 UK students accepted an offer of an undergraduate university place in 2018, compared with only 217,000 students in 1994, an increase of 94% (Bolton, 2018). However, the expansion of student numbers has not typically been accompanied by an equivalent increase in the number of academics, resulting in increased demands on teaching staff. In the UK, staff:student ratios in the 1990s were typically 14:1, whereas more recent estimates indicate a ratio of 17:1 (Court, 2012). This is an international phenomenon; for example in Australia the average student staff ratio increased from 17:1 in 2000 to 22:1 in 2010, representing a 26% increase in just a decade (Prosser & Trigwell, 2014). There is therefore a need to understand the impact of these changes on both students and academic staff.

To maintain provision with fewer resources, most institutions have increased class sizes, sometimes significantly. Although teaching at scale is part of the day-to-day activity of many academics, there is no accepted definition of what constitutes a 'large class' (Maringe & Sing, 2014). Numerical estimates range from 40 to over 1000 students, but these vary considerably across disciplines and contexts (Allais, 2014; Arvanitakis, 2014; Mulryan-Kyne, 2010; Prosser & Trigwell, 2014). Within Science Technology Engineering and Mathematics (STEM) undergraduate programmes, the majority of large class teaching is to first year introductory courses, often with students from multiple sub-disciplines taught together; for example, an introductory biochemistry class may include students from biochemistry, biology, zoology, pharmacy, biomedical sciences etc. (Cash, Letargo, Graether, & Jacobs, 2017; Stains et al., 2018). Teaching large classes in STEM must also extend beyond the lecture theatre to the laboratory/field environment if students are to develop technical skill alongside disciplinary knowledge (Stains et al., 2018).

Teaching at scale is typically presented as a 'problem' for academics, with large classes seen as challenging environments that must be tolerated or even endured. Increased numbers of students results in increased academic burden, particularly with respect to assessment and feedback (Allais, 2014; Cuseo, 2007). However, the challenges of large class teaching are not limited to additional students, but also include a more diverse student body (Maringe & Sing, 2014). As greater proportions of the population have entered higher education, universities have moved from an 'elite' model where only a small number are educated to a high standard, to a more comprehensive model that includes students from diverse socioeconomic, cultural and educational backgrounds (Maringe & Sing, 2014). Mulryan-Kyne (2010) highlights a range of challenges to large class teaching, including the abilities, backgrounds and experiences of the student body as well as the skills or competencies of the instructor.

The literature on the impact of class size on student learning, satisfaction and outcomes is contradictory (Cuseo, 2007; Kokkelenberg, Dillon, & Christy, 2008; W. J. McKeachie, 1980; Williams, Cook, Quinn, & Jensen, 1985). Some have argued that the large class experience is overwhelmingly negative; for example Cuseo (2007) presents eight negative effects of large class teaching, including a reliance on lecturing, reduced involvement of students, reduced frequency and quality of student-instructor interaction, and lower achievement and performance. However, this argument is reliant on the assumption that the lecture experience is didactic; Cuseo (2007) emphasises how active learning pedagogies (e.g. use of technology, breakout into small group discussions) can improve student engagement. There are examples of class size affecting student evaluations of teaching (Crittenden, Norr, & Lebailly, 1975; Wood, Linsky, & Straus, 1974), but others find minimal impact of class size on student satisfaction with teaching (Marsh, Overall, & Kesler, 1979). Looking beyond satisfaction to success, some studies have modelled the relationship between the number of students on a course and attainment (Kokkelenberg et al., 2008; Williams et al., 1985). These studies conclude that there is only a small negative impact of class size, consistent with equivalent models of school level class sizes (Smith & Glass, 1980). The greatest effect is seen when class sizes increase from a handful of students to around 50; increasing class size beyond this has limited effects. However, this suggests that other components of the learning environment have greater influence than number of students (Benton & Cashin, 2012; Kokkelenberg et al., 2008; Williams et al., 1985). It has been argued that large classes make little difference to end-of-course test performance, but that large classes do not favour the development of higher level thinking or student motivation (Wilbert J. McKeachie, Lin, Moffett, & Daugherty, 1978; McKeachie, 1980). The literature is therefore inconsistent, and it is difficult to ascertain whether there is an 'optimal' class size.

While the impacts of large class teaching on student satisfaction and achievement have been studied for several decades, there has been less consideration of the impact of large class teaching on academic instructors. Hornsby & Osman (2014) highlight this knowledge gap, and call for increased research into the impact of large class teaching on academics themselves, academic infrastructure and academic outputs. Some studies indicate that academics generally see the expansion of higher education as resulting in reduced quality, increased workload and reduced academic autonomy (Akalu, 2016; Giannakis & Bullivant, 2016). Some reflective accounts describe approaches to large class teaching by individual academics; for example Arvanitakis (2014) describes his approaches to teaching a first year sociology course with over 1000 students enrolled, and his growing confidence in this environment. However these accounts are rare, and there are few studies which systematically attempt to capture the academic experience of large class teaching. One study of both student and instructor experiences indicates that both groups see lack of engagement and distractions by other students as the primary concerns in the large class environment (Cash et al., 2017). However there are few studies that systematically attempt to capture the academic experience of large class teaching.

This study therefore aims to address this gap by exploring the experiences of academics who teach large classes, with a particular focus on the affective domain (Krathwohl, Bloom & Masia, 1964). We restrict our sample population to academics working within scientific disciplines (e.g. life sciences, chemistry, physics and geology). Our emphasis is face-to-face teaching; online teaching (e.g. through Massive Open Online Courses) at scale has unique challenges which are beyond the context of this study. Our specific aims are:

1. to determine what constitutes a 'large class' in the mind of academics;
2. to explore how academics perceive the experience of large class teaching;
3. to understand the challenges academics face when teaching large classes;
4. to determine whether teaching context influences the academic experience of teaching large classes; and
5. to determine to what extent academics have received training that specifically relates to large class teaching.

Methods

Survey Development, Distribution and Response Rates

To explore the academic experience of large class teaching we adopted a survey based approach, allowing systematic comparison of experiences. The survey was developed to explore a range of different staff experiences of large class teaching, and included Likert style questions and free text responses (See Supplemental Information 1 for full survey questions), therefore allowing analysis from both quantitative and qualitative perspectives. The survey was piloted with three members of staff at the University of Hull who were not included in the final survey population. Ethical approval for the work was granted by the University of Hull Faculty of Science and Engineering Ethics Committee (Project code: FEC_2019_11). The survey was hosted by www.onlinesurveys.ac.uk and was distributed electronically via the social media accounts of the

researchers, and as a paper copy at the education session of the Society of Experimental Biology Annual Main Meeting 2018. 80 responses were obtained, with participants representing a variety of career stages, institution types (research- or teaching-focused, or neither) and contract types (Table 1). 64 of the 80 (80%) responses were from UK based academics in the Life Sciences.

Table 1: Demographics of Participants

Demographic Indicator		Number of participants
Career Stage	Junior academic	36
	Senior academic	43
	Other	1
Subject Area	Life Sciences	73
	Physical Sciences	7
Country	UK	71
	Non UK/not stated	9
Institution Type	Research focused university	42
	Teaching focused university	22
	Not sure/other	16
Current Contract Type	Teaching only	19
	Teaching focused	41
	Equal balance between teaching and research	16
	Research focused	3
	Other	1
Teaching Qualification/Fellowship	Yes	60
	No but working towards	8
	No	12
Gender Identity	Female	53
	Male	24
	Prefer not to say	3

Data analysis

Questionnaire responses were exported from the online platform, and imported into R (R core Team, 2018) for analysis. We grouped participants by career stage, with 'Junior Academics' defined as lecturers, teaching fellows, teaching assistants, assistant professors etc., and 'Senior Academics' as senior lecturers, readers, professors, associate professors.

For class size estimates some participants indicated a range e.g. 25-50 students, or expressed these in terms of greater than/less than a number of students. Where a range was indicated we took the highest value provided as the indicator of class size e.g. 25-50 was assumed to be 50. Where greater/less than estimates were provided we took the value provided as the indicator of class size. Class size data was not normally distributed (Shapiro-Wilk test; Small classes $W = 0.82$, $P < 0.001$;

Medium classes $W = 0.66$, $P < 0.001$; Large classes $W = 0.66$, $P < 0.001$), so non-parametric statistics were used, with significance defined at $\alpha = 0.05$.

For quantitative analysis of Likert style questions, responses were numerically coded as 1 = strongly disagree; 5 = strongly agree etc. Cronbach's alpha for the 17 Likert items was 0.87, indicating high levels of internal consistency. Data were assumed to be non-normally distributed, so non-parametric statistics were used, with significance defined at $\alpha = 0.05$, or a Bonferroni corrected $\alpha = 0.05/n_{tests}$ where multiple tests were performed on the same set of values. Graphical representation of Likert questions was created using the R package 'likert' (Bryer & Speerschneider, 2016).

For analysis of words associated with large class teaching, all free text responses were collated and then a list of non-duplicated words within the dataset generated. Words were then stemmed (e.g. exciting and excitement were stemmed to excited) and frequencies of word use determined. The consensus list of words were scored as +1 for a positive word, -1 for a negative word and 0 for a neutral word; scoring was verified by an individual not part of the research team. Wordclouds were created using www.wordclouds.com.

Analysis of free-text responses was conducted in NVivo12, taking an inductive approach to coding based on Braun & Clarke (2006). Responses were initially coded at the level of sentence/comment, and then collated into broader categories. This coding and categorisation was conducted twice to check for consistency ($Kappa = 0.73$). Coding and categorisation were then discussed and checked with an independent researcher, where final categories were determined.

Results

Perceptions of class size

We were interested to find out what our participants defined as a 'large class', so asked participants how many students a small, medium or large class contains, in their view. Small classes ranged from 1 to 100, with a median size of 20. Medium classes ranged from 20 to 400, with a median of 70. Large classes ranged from 60 to 1200, with a median of 100. There was therefore considerable variation in the definitions of class size used by our participants (Figure 1A). There was no difference in these class size definitions as a function of institution type (research or teaching focused), contract type or career stage (Supplemental Table 1).

We also asked participants what was the largest class size they had ever been responsible for in a variety of formats (Figure 1B). Lectures were associated with the largest classes, with a median of 280 students, followed by practicals (90 students), computational/workshops (76) and day field trips (50).

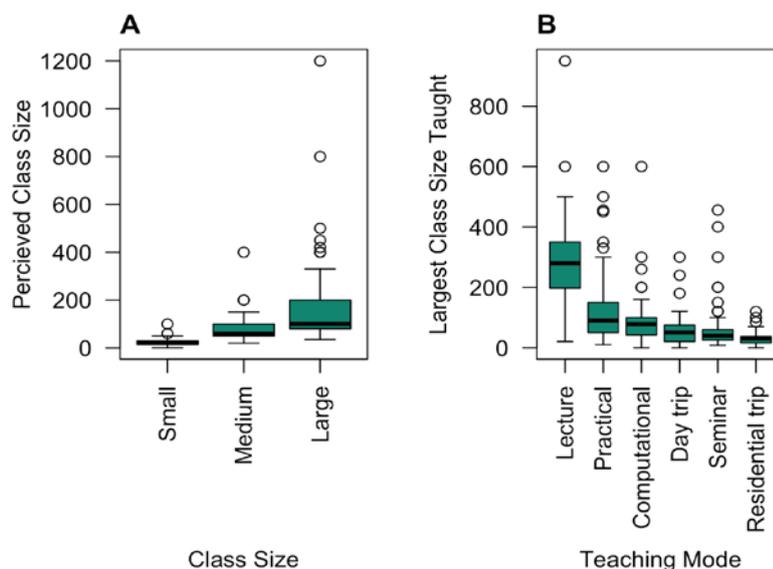


Figure 1: Perceived and Actual Class Sizes. A: Perceived class sizes, B: Largest class sizes actually taught. Boxes indicate the interquartile range, thick lines the median, whiskers the range and circles indicate outliers.

Perceptions of large class teaching

To explore experiences of large class teaching from the perspective of the affective domain, we asked participants to give three words to describe how they felt about teaching large classes (Figure 2). The most commonly used words were 'challenging' (n = 24), followed by 'excited' (n = 16), 'impersonal' (n = 7) and 'nervous' (n = 7). Some participants used three positive words (e.g. 'fun', 'energised' and 'proud'), whereas others used a mixture of words (e.g. 'challenging', 'enjoyment', 'scary'), or three negative words (e.g. 'nervous', 'frustrated' and 'boring'). There was therefore a wide range of affective domain responses within our dataset. To allow comparisons to be made within the dataset we assigned each word a score of either -1, 0 or 1 to indicate negative, neutral or positive, and calculated the total word score for each participant. The most common total word score was -1 (n = 23), but scores ranged from +3 (n = 3) to -3 (n = 13). There was no significant difference in the total word score as a function of either institution type (Kruskal Wallis H = 5.8 d.f. = 4, P = 0.22), career stage (H = 0.18, d.f. = 1, P = 0.67) or contract type (H = 2.93, d.f. = 3, P = 0.40), therefore we conclude that affective domain responses to large class teaching are not driven by teaching context.



Figure 2: Affective domain responses to large class teaching. Participants were asked to provide three words to describe how they felt about large class teaching. Words used by a single participant are removed for clarity. Sizes of words are proportional to the frequency in the dataset.

We also asked participants a series of Likert-style questions to explore how they felt about particular aspects of large class teaching (Figure 3). These were grouped by overall feelings about large class teaching (Figure 3A), resources to support large class teaching (Figure 3B) and the student experience of large class teaching (Figure 3C). For all questions except *"I change my teaching methods when teaching large classes"* there was a full spectrum of responses from 'Strongly Disagree' to 'Strongly Agree'. The strongest level of agreement was for the statement *"I change my teaching methods when teaching large classes"* (% agreement = 94%). The lowest level of agreement was for *"I am able to address the diverse needs of individual students effectively when teaching large classes"* (% agreement = 24%). Questions for which there was a significant positive bias in responses were *"I enjoy large class teaching"*, *"I change my teaching methods when teaching large classes"* and *"I change my assessment methods when teaching large classes"* (Supplemental Table 2). Questions with a significant negative bias were *"I teach in the same way independent of class size"*, *"I have had sufficient training in how to teach large classes effectively"*, *"My institution provides enough administrative support for teaching large classes"* and *"I am able to address the diverse needs of individual students effectively when teaching large classes"* (Supplemental Table 2).

We were interested to see if teaching context had any influence on opinions of large class teaching, so analysed the Likert questions by institution type, contract type and career stage (Supplemental Table 2). The only question for which there was a difference was *"I have sufficient demonstrators/GTAs/teaching assistants available to me to support teaching in large classes"*; those from teaching-focused institutions were more likely to disagree with the statement than those in research-focused institutions (Kruskal Wallis H = 11.7, d.f. = 3, P < 0.001**).

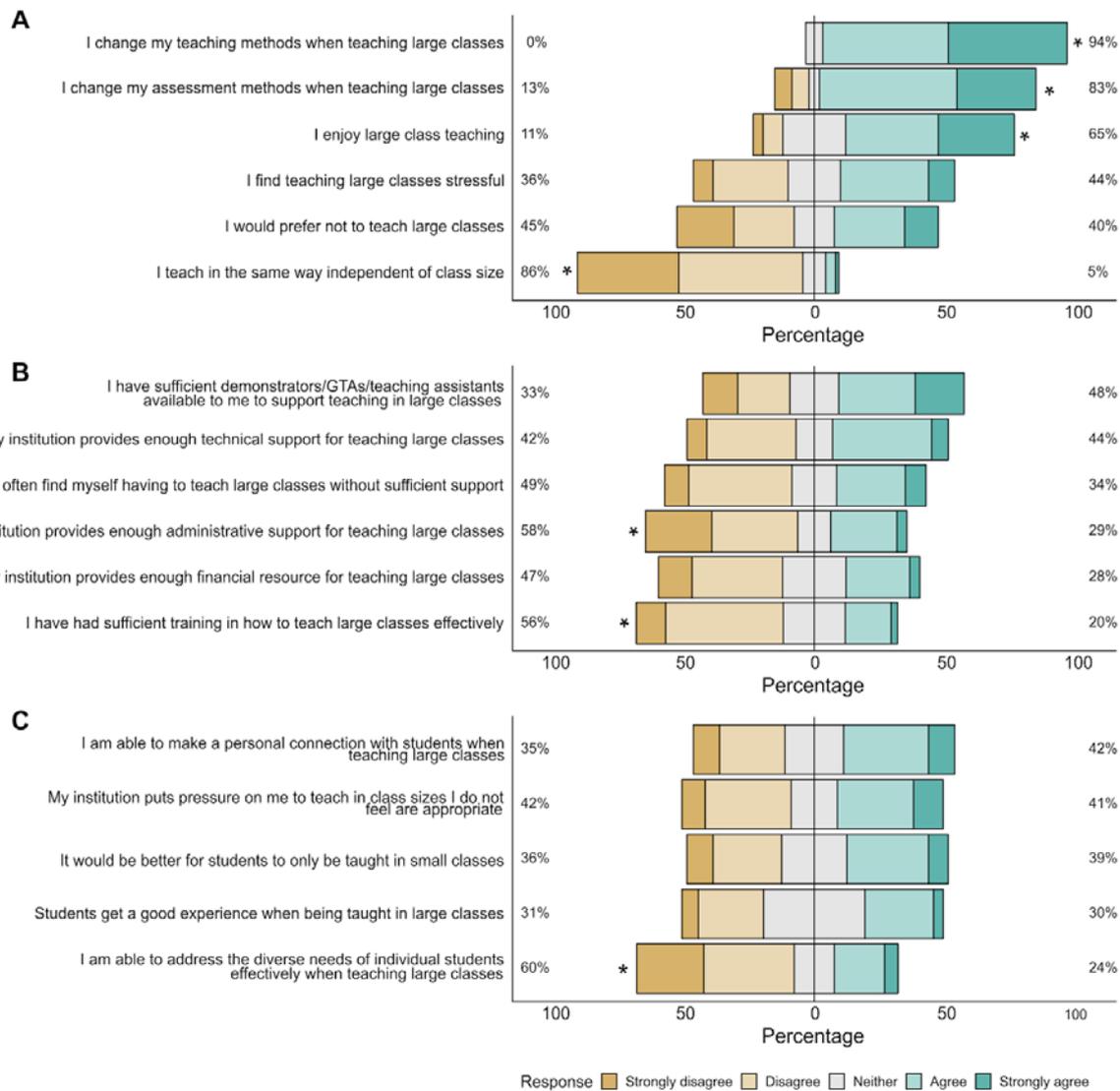


Figure 3: Responses to Likert Scale questions about large class teaching. Questions are divided into A: General perceptions, B: Resources and C: Student experience of large class teaching. % agreement is displayed to the right hand side of each plot, % disagreement to the left, % neutral responses are not shown for clarity. For each plot, questions are presented with the strongest level of agreement at the top. Questions with a median significantly different to 3 (neither) are indicated with an asterisk.

Challenges of large class teaching

To understand perceptions of large class teaching at a qualitative level, we asked participants to describe the challenges they had faced when teaching large classes (Figure 4). We obtained a wide variety of responses, which could broadly be grouped into seven categories, illustrated by direct quotations from the survey in Table 2. The most frequently discussed theme was 'Engagement/participation' ($n = 49$), where academics discussed the challenges of maintaining the attention of large groups and getting students to participate in activities. The next most frequently discussed challenge was 'Addressing individual needs' ($n = 32$), which was usually framed in terms of balancing the needs of students of differing academic ability, but also included the challenges of teaching to multiple programmes and the needs of learners with disabilities. Challenges relating to 'Logistics' included being allocated appropriate teaching spaces, finding time to deal with student queries and running sessions multiple times ($n = 23$). 'Gauging understanding' included descriptions of being unable to determine if students had understood a particular point, and the lack of meaningful interactions ($n = 17$). Student behaviour concerns included students chatting or using mobile phones, disruption of classes and two more serious examples of challenging behaviour such as taunting of academics ($n = 10$). The final category of challenge was 'Technology', with academics expressing concern

at being reliant on IT equipment, microphones, lecture capture systems etc., and how these were amplified when dealing with large classes or lecture rooms ($n = 7$).

Table 2: Challenges of large class teaching described by participants. Frequency of use is indicated as number of mentions within all responses; most participants mentioned multiple challenges. Only categories that had five or more mentions are presented.

Category	Illustrative quotations	Number of times mentioned
Engagement/ participation	<i>"Keeping the attention of everyone, keeping everyone focused"</i> <i>"Reluctance for learners to engage and respond to open questioning."</i>	49
Addressing individual needs	<i>"Accommodating a very wide range of ability in the same class - not leaving the weakest students behind while not boring the strongest."</i> <i>"It is hard to keep all students on all programmes engaged all the time as different bits of the subject matter are of greater or lesser relevance to different parts of the class"</i>	32
Logistics	<i>"Dealing with a large number of questions from a queue of students at the end is always time-consuming."</i> <i>"Juggling split practical groups and timetable problems, being allocated unsuitable teaching spaces or dumped in the worst timetable slots"</i>	23
Gauging understanding	<i>"Knowing whether or not something like an explanation or an activity worked is very difficult."</i> <i>"Unable to gauge student reaction or level of engagement"</i>	17
Student behaviour	<i>"Many students arrive late as they feel less conspicuous than sneaking in to a small teaching group."</i> <i>"Poor professional behaviour in the students. They can lapse into a non-education setting approach, such as chatting, sniggering, texting, sleeping, fighting, eating, drinking."</i>	10
Technology	<i>"The IT support is always a concern, e.g. if the microphone dies. Once, there was a powercut and I had to lecture without PowerPoint."</i> <i>"Technology problems are enhanced when teaching bigger classes"</i>	6



Figure 4: Word cloud of responses to “Please describe the challenges you have faced when teaching large classes”. Words occurring fewer than 5 times in the dataset are removed for clarity. Sizes of words are proportional to the frequency in the dataset.

Training in large class teaching

We asked our participants whether they had had training that specifically addressed large class teaching (Table 3). Only 21 of 79 participants (26%) who responded had had training that specifically dealt with large class teaching; 12 participants had not received any training in how to teach, and 46 had received training in how to teach that did not address teaching large classes. Nineteen participants (24%) had neither received training in large class teaching nor gained a teaching qualification/fellowship at the time of completing the survey. We were therefore interested to see if these participants had different perceptions of large class teaching. There was no significant difference in the total word score on the basis of training ($H = 0.12$, $d.f. = 1$, $P = 0.73$). For 15 of the 17 Likert questions there was no difference in response on the basis of training (Supplemental Table 2); the exceptions to this were “*I enjoy large class teaching*” ($H = 6.37$, $d.f. = 1$, $P = 0.011^*$) and “*I have had sufficient training in how to teach large classes effectively*” ($H = 6.37$, $d.f. = 1$, $P = 0.011^*$), where participants with no training were less likely to agree with those statements.

Table 3: Training status of participants. Note that one participant did not answer this question, therefore $n = 79$.

		Teaching qualification/fellowship			
		No/working towards	Yes	Total	% of participants
Training received	No training	7	5	12	15%
	Training didn't cover large class teaching	12	34	46	58%
	Training did cover large class teaching	1	20	21	27%
	Total	20	59	79	100%

Discussion

In this study we aimed to explore academic perceptions of large class teaching. It should be noted that there was a strong bias within our dataset towards life sciences academics teaching within the UK, so interpretation of findings should be conducted through this lens. We do not present this survey as a complete understanding of the STEM academic experience, but consider it a useful ‘snapshot’ of perceptions of large class teaching. We find that most academics consider a large class to contain 100 students or more, but that there is significant individual variation in the perception of class sizes. There was considerable variation in perceptions of large class teaching; some academics viewed large class teaching as a very positive experience, some as a negative experience and some had mixed feelings. We also find that while the majority of academics have received training in how to teach, the majority had not received specific guidance about large class teaching.

The term ‘large class’ is open to interpretation (Allais, 2014; Arvanitakis, 2014; Maringe & Sing, 2014; Mulryan-Kyne, 2010). In our study, academics typically saw 100 students as a large class, but there was considerable variation in this; the largest

reported class size in our sample was 950 students. Most of our participants had taught lectures to 200 or more students, and taught practicals of 50 or more. One study of academics and students in a US university arrived at an estimate of 240 students as defining a large class (Cash et al., 2017), which may reflect differences in US and UK models of education. While it was useful in the context of this study to quantify class size, others have sought a more qualitative definition. Hornsby & Osman (2014) consider a large class size to be an environment where the number of students negatively impacts on the quality of student learning, and note that this is dependent on the requirements of the discipline and pedagogical goals (Hornsby & Osman, 2014; Mulryan-Kyne, 2010).

When discussing the challenges of large class teaching, the majority of our participants described issues relating to engagement, student participation, meeting the needs of individuals and gauging the level of understanding of the audience, particularly in the context of a large lecture. These are consistent with the findings of Cash et al., (2017) who found that instructors describing large class teaching emphasised a lack of student engagement, a feeling of disconnection, and disruption by students. Our study therefore suggests that the primary challenge of teaching at scale from an academic perspective is building personal connections with students, and not about particular pedagogies. Allais (2014) proposes that lectures are intrinsically valuable teaching spaces, being a unique opportunity for (i) discussion and presentation of key knowledge or concepts and (ii) the building of an intellectual community through shared focus on ideas. Development of an intellectual community is dependent on a shared physical space and the energy of interactions, which are actively compromised in a large class environment (Allais, 2014). For example, if one sub-group of students is bored by an activity, this impacts on the whole group, which therefore reduces engagement and the shared focus needed for effective learning (Allais, 2014). While some of our survey participants described active disruption by a small number of students, the more common concern was that not all students were equally engaged, and that it was difficult to ascertain whether all students were keeping up with the material presented.

Massification of higher education and resultant increases in class size are often framed as a problem, and that given the choice most academics would rather teach small classes (Allais, 2014; Cuseo, 2007). However, many of the academics in our survey population had positive views of large class teaching, and actively enjoyed it. There was an equal balance of agreement and disagreement with the statements 'I would prefer not to teach large classes' and 'It would be better for students to only be taught in small classes', indicating there is not a significant preference for small class teaching in our survey population. Hornsby and Osman (2014) note that the "*challenges of large class teaching can be overcome when lecturers privilege student learning in their pedagogical designs*", and call for the large class debate to be reframed in terms of opportunities as well as challenges. Mulryan-Kyne (2010) highlights that many studies indicate the skill and expertise of the teacher is more significant than the number of students in a class *per se*. Prosser and Trigwell (2014) argue that success in large class contexts is associated with moving from an 'information transfer, teacher focused' approach to a 'conceptual change, student focused' perspective, and note that this requires instructors to challenge their assumptions about education (Prosser & Trigwell, 2014). Many of our participants mentioned active learning strategies such as the use of interactive polling and in-class activities, indicating that they had actively adapted their teaching practices to emphasise student learning. However, our participants also described the challenge of getting all students to engage with these activities, suggesting that either their approaches were still too teacher-focused, or that classroom management and setting expectations was also required for success.

Our survey also underlines a deficit in academic development, as the majority of our participants stated that they had received no training that specifically addressed the issues around large class teaching. Given that almost all STEM academics can be expected to teach in a large class context, we see this lack of support as a matter of concern. Prosser and Trigwell (2014) note that adopting student-centred approaches in the large classroom may be challenging for academics, and it is not easy to get students to adopt a deep level approach to study in a larger class. A wide range of pedagogical strategies for large class teaching in both general and STEM contexts have been described (Carbone, 1998; Chowrira, Smith, Dubois, & Roll, 2019; Eichler & Peeples, 2016; Hornsby, Osman & De Matos-Ala, 2013; Jin & Bierma, 2013; Sharma, Millar, & Seth, 1999; Strawson, 2013; Wood, 2009), and we do not attempt to review these here. For educators looking for large class teaching strategies, we particularly recommend the resources collated by the University of Reading (UK), which include suggestions for activities that require either 5 or 10 minutes of preparation time as well as more substantive adaptations to large class teaching (Strohfeldt & Pye, 2017). However, we also call on academic developers to incorporate practical strategies for teaching and assessing at scale into training courses, and to provide tailored support for instructors who are faced with particularly large increases in cohort size.

Conclusions and implications for practice

In conclusion, we find that academics have divergent opinions about large class teaching, and that this variation is mostly due to individual characteristics and preferences rather than a systematic response to institution type, career stage, country of practice or training in how to teach. We find evidence that training in teaching often lacks a specific consideration of dealing with large classes, so therefore recommend that academic development programmes set aside time to support academics dealing with large cohorts. We recommend that this training includes pedagogical strategies to engage large cohorts, including the use of technology enhanced learning. We also recommend academic programmes specifically consider classroom management and dealing with anxiety when teaching large classes, as there is a significant affective domain

component to teaching. We consider that balancing these two needs in academic development is essential if academics are to maximise their effectiveness and confidence when dealing with the demands of modern higher education.

Biographies

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References

- Akalu, G. A. (2016). Higher Education “Massification” and challenges to the professoriate: Do academics’ conceptions of quality matter? *Quality in Higher Education*, 22(3), 260–276. <https://doi.org/10.1080/13538322.2016.1266230>
- Allais, S. (2014). A critical perspective on large class teaching: The political economy of massification and the sociology of knowledge. *Higher Education*, 67(6), 721–734. <https://doi.org/10.1007/s10734-013-9672-2>
- Arvanitakis, J. (2014). Massification and the large lecture theatre: From panic to excitement. *Higher Education*, 67(6), 735–745. <https://doi.org/10.1007/s10734-013-9676-y>
- Benton, S. L., & Cashin, W. E. (2012). Student Ratings of Teaching: A Summary of Research and Literature. Retrieved from The IDEA Center website: https://www.ideaedu.org/Portals/0/Uploads/Documents/IDEA%20Papers/IDEA%20Papers/PaperIDEA_50.pdf
- Bolton, P. (2018). Higher education student numbers: Briefing Paper (No. 7857). Retrieved from House of Commons Library website: researchbriefings.files.parliament.uk/documents/CBP-7857/CBP-7857.pdf
- Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp063oa>
- Bryer, J. & Speerschneider, K. (2016). likert: Analysis and Visualization Likert Items. Retrieved from <https://CRAN.R-project.org/package=likert>
- Carbone, E. (1998). Teaching Large Classes: Tools and Strategies. *Survival Skills for Scholars*, Volume 19. Retrieved from <https://eric.ed.gov/?id=ED428614>
- Cash, C. B., Letargo, J., Graether, S. P. & Jacobs, S. R. (2017). An Analysis of the Perceptions and Resources of Large University Classes. *CBE Life Sciences Education*, 16(2). <https://doi.org/10.1187/cbe.16-01-0004>
- Chowrira, S. G., Smith, K. M., Dubois, P. J. & Roll, I. (2019). DIY productive failure: Boosting performance in a large undergraduate biology course. *NPJ Science of Learning*, 4, 1. <https://doi.org/10.1038/s41539-019-0040-6>
- Crittenden, K. S., Norr, J. L. & Lebailly, R. K. (1975). Size of university classes and student evaluations of teaching. *The Journal of Higher Education*, 46(4), 461–470. <https://doi.org/10.2307/1980673>
- Court, S. (2012). An analysis of student:staff ratios and academics’ use of time, and potential links with student satisfaction. Retrieved from https://www.ucu.org.uk/media/5566/An-analysis-of-studentstaff-ratios-and-academics-use-of-time-and-potential-links-with-student-satisfaction-Dec-12/pdf/ucu_sranalysis_dec12.pdf
- Cuseo, J. (2007). The empirical case against large class size: Adverse effects on the teaching, learning, and retention of first-year students. *The Journal of Faculty Development*, 21(1), 5–21. Retrieved from <https://www.ingentaconnect.com/content/nfp/jfd/2007/00000021/00000001/art00001>
- Eichler, J. F. & Peeples, J. (2016). Flipped classroom modules for large enrollment general chemistry courses: A low barrier approach to increase active learning and improve student grades. *Chemical Education Research and Practice*, 17(1), 197–208. <https://doi.org/10.1039/C5RP00159E>
- Giannakis, M. & Bullivant, N. (2016). The massification of higher education in the UK: Aspects of service quality. *Journal of Further and Higher Education*, 40(5), 630–648. <https://doi.org/10.1080/0309877X.2014.1000280>

- Hornsby, D. J. & Osman, R. (2014). Massification in Higher Education: Large classes and student learning. *Higher Education: The International Journal of Higher Education and Educational Planning*, 67(6), 711–719. <https://doi.org/10.1007/s10734-014-9733-1>
- Hornsby, D. J., Osman, R. & De Matos-Ala, J. (2013). Large-class pedagogy: Interdisciplinary perspectives for quality higher education. Retrieved from <https://market.android.com/details?id=book-6-RengEACAAJ>
- Jin, G. & Bierma, T. (2013). STEM for non-STEM majors: Enhancing science literacy in large classes. *Journal of College Science Teaching*, 42(6), 20–26. Retrieved from https://www.jstor.org/stable/43632151?casa_token=UsW2lj1UFzoAAAAA:6Pj7OXVb4RdsB8sv6AETPS4eVauiryjTAMJUmdWGqVV97zBhjhKU-KVcS4PSDRP6Pjo4AHB-7tYcJ14RIH8-wM-9xFRNeZyrjMLGScKtTle2Nm3GDw
- Kokkelenberg, E. C., Dillon, M. & Christy, S. M. (2008). The effects of class size on student grades at a public university. *Economics of Education Review*, 27(2), 221–233. <https://doi.org/10.1016/j.econedurev.2006.09.011>
- Krathwohl, D. R., Bloom, B. S. & Masia, B. B. (1964). *Taxonomy of educational objectives, Book II. Affective domain*. New York, NY. : David McKay Company, Inc.
- Maringe, F. & Sing, N. (2014). Teaching large classes in an increasingly internationalising higher education environment: pedagogical, quality and equity issues. *Higher Education*, 67(6), 761–782. <https://doi.org/10.1007/s10734-013-9710-0>
- Marsh, H. W., Overall, J. U. & Kesler, S. P. (1979). Class Size, Students' Evaluations, and Instructional Effectiveness. *American Educational Research Journal*, 16(1), 57–70. <https://doi.org/10.3102/00028312016001057>
- McKeachie, W. J. (1980). Class size, large classes, and multiple sections. Academe. Retrieved from https://www.jstor.org/stable/40249328?casa_token=sxz1RwSIn_4AAAAA:ojwamW2t8VbU0BMUUT87Hhp0rrwY5tj8wmWGrRj_568niQH2GVJ4mVy_gZQIFx_U5E2vqi65PzdJxLRnQeKufG6WRJzp6CY_QZPAk2bAzTNw_3jV2g
- McKeachie, W. J., Lin, Y.-G., Moffett, M. M. & Daugherty, M. (1978). Effective Teaching: Facilitative vs. Directive Style. *Teaching of Psychology*, 5(4), 193–194. https://doi.org/10.1207/s15328023top0504_6
- Mulryan-Kyne, C. (2010). Teaching large classes at college and university level: Challenges and opportunities. *Teaching in Higher Education*, 15(2), 175–185. <https://doi.org/10.1080/13562511003620001>
- Prosser, M. & Trigwell, K. (2014). Qualitative variation in approaches to university teaching and learning in large first-year classes. *Higher Education*, 67(6), 783–795. <https://doi.org/10.1007/s10734-013-9690-0>
- R Core Team. (2018). R: A Language and Environment for Statistical Computing. Retrieved from <https://www.R-project.org/>
- Sharma, M. D., Millar, R. & Seth, S. (1999). Workshop tutorials: accommodating student-centred learning in large first year university physics courses. *International Journal of Science Education*, 21(8), 839–853. <https://doi.org/10.1080/095006999290327>
- Smith, M. L. & Glass, G. V. (1980). Meta-analysis of research on class size and its relationship to attitudes and instruction. *American Educational Research Journal*, 17(4), 419–433. <https://doi.org/10.3102/00028312017004419>
- Stains, M., Harshman, J., Barker, M. K., Chasteen, S. V., Cole, R., DeChenne-Peters, S. E., ... Young, A. M. (2018). Anatomy of STEM teaching in North American universities. *Science*, 359(6383), 1468–1470. <https://doi.org/10.1126/science.aap8892>
- Strawson, H. (Ed.). (2013). *53 Ways to Deal with Large Classes (Professional and Higher Education)*. Retrieved from <https://www.amazon.co.uk/Large-Classes-Professional-Higher-Education/dp/1907076565>
- Strohfeldt, K. & Pye, R. (2017). *Large Class Education Toolkit*. Retrieved from University of Reading website: https://www.reading.ac.uk/web/files/cqsd/V4_Interactive_Education_Toolkit.pdf
- Williams, D. D., Cook, P. F., Quinn, B. & Jensen, R. P. (1985). University class size: Is smaller better? *Research in Higher Education*, 23(3), 307–318. <https://doi.org/10.1007/BF00973793>
- Wood, K., Linsky, A. S. & Straus, M. A. (1974). Class Size and Student Evaluations of Faculty. *The Journal of Higher Education*, 45(7), 524–534. <https://doi.org/10.1080/00221546.1974.11776994>

Wood, W. B. (2009). Innovations in teaching undergraduate biology and why we need them. *Annual Review of Cell and Developmental Biology*, 25, 93–112. <https://doi.org/10.1146/annurev.cellbio.24.110707.175306>

Supplemental Table 1: Perceptions of Class Size by Teaching Context

	Small	Medium	Large
Median number of students (min - max)	20 (1 - 100)	60 (20 - 400)	100 (35 - 1200)
Results of Kruskal Wallis Tests for differences by:			
Institution Type	H = 0.16, d.f. = 4, P = 0.98	H = 7.12, d.f. = 4, P = 0.13	H = 8.62, d.f. = 4, P = 0.07
Contract Type	H = 2.48, d.f. = 4, P = 0.65	H = 0.94, d.f. = 4, P = 0.92	H = 5.99, d.f. = 4, P = 0.20
Career Stage	H = 0.19, d.f. = 1, P = 0.66	H = 0.09, d.f. = 1, P = 0.77	H = 0.35, d.f. = 1, P = 0.55

Supplemental Table 2: Statistical Analysis of Likert Questions by teaching context. Tests for median different to three show the results of Wilcoxon test. Analysis by teaching context show the results of Kruskal-Wallis Chi-square tests, with significance defined at $\alpha = 0.05/4 = 0.0125$ to include a Bonferroni correction for multiple testing. Significant results are highlighted in bold. (R) indicates reverse-scored items.

No.	Likert Prompt	Median	Median significantly different to 3	Institution Type (d.f. = 4)	Contract Type (d.f. = 4)	Career Stage (d.f. = 1)	Training Status (d.f. = 1)
1	I enjoy large class teaching	4	V = 1582.5, P <0.001**	H = 4.86, P = 0.30	H = 4.31, P = 0.37	H = 1.25, P = 0.26	H = 6.37, P = 0.011*
2	Students get a good experience when being taught in large classes	3	V = 577.5, P = 0.71	H = 1.59, P = 0.81	H = 3.46, P = 0.48	H = 0.89, P = 0.35	H = 0.03, P = 0.87
3	I teach in the same way independent of class size (R)	2	V = 120.5, P <0.001**	H = 5.79, P = 0.22	H = 4.07, P = 0.40	H = 0.44, P = 0.50	H = 1.18, P = 0.27
4	My institution provides enough technical support for teaching large classes	3	V = 1185, P = 0.94	H = 1.71, P = 0.79	H = 2.81, P = 0.59	H = 0.70, P = 0.40	H = 2.44, P = 0.12
5	I change my teaching methods when teaching large classes	4	V = 2628, P <0.001**	H = 1.18, P = 0.88	H = 6.78, P = 0.14	H = 0.03, P = 0.86	H = 5.88, P = 0.015
6	I would prefer not to teach large classes (R)	3	V = 950, P = 0.30	H = 4.31, P = 0.36	H = 1.11, P = 0.89	H = 1.62, P = 0.20	H = 0.032, P = 0.86
7	I have had sufficient training in how to teach large classes effectively	2	V = 469, P <0.001**	H = 3.28, P = 0.51	H = 1.63, P = 0.80	H = 0.02, P = 0.88	H = 6.37, P = 0.011*
8	My institution provides enough administrative support for teaching large classes	2	V = 644, P <0.001**	H = 3.97, P = 0.41	H = 3.22, P = 0.52	H = 1.28, P = 0.26	H = 5.96, P = 0.014
9	I am able to address the diverse needs of individual students effectively when teaching large classes	2	V = 540.5, P <0.001**	H = 5.62, P = 0.26	H = 3.45, P = 0.49	H = 0.29, P = 0.58	H = 0.37, P = 0.54
10	It would be better for students to only be taught in small classes (R)	3	V = 908.5, P = 0.96	H = 2.28, P = 0.68	H = 1.49, P = 0.82	H = 0.48, P = 0.48	H = 0.18, P = 0.65
11	My institution provides enough financial resource for teaching large classes	3	V = 605.5, P = 0.02*	H = 1.29, P = 0.86	H = 7.50, P = 0.11	H = 0.24, P = 0.62	H = 1.42, P = 0.23
12	I find teaching large classes stressful (R)	3	V = 1148.5, P = 0.44	H = 2.41, P = 0.66	H = 3.53, P = 0.47	H = 0.13, P = 0.71	H = 0.30, P = 0.58
13	My institution puts pressure on me to teach in class sizes I do not feel are appropriate (R)	3	V = 1092.5, P = 0.89	H = 2.28, P = 0.51	H = 4.21, P = 0.37	H = 0.21, P = 0.64	H = 3.38, P = 0.07
14	I change my assessment methods when teaching large classes	4	V = 2288.5, P <0.001**	H = 4.52, P = 0.21	H = 9.00, P = 0.06	H = 0.00, P = 0.94	H = 2.98, P = 0.08
15	I have sufficient demonstrators/GTAs/teaching assistants available to me to support teaching in large classes	3	V = 1111, P = 0.22	H = 11.7, P <0.001**	H = 2.21, P = 0.69	H = 0.88, P = 0.35	H = 0.11, P = 0.75
16	I often find myself having to teach large classes without sufficient support	3	V = 852, P = 0.25	H = 1.87, P = 0.60	H = 3.13, P = 0.54	H = 1.62, P = 0.20	H = 3.36, P = 0.07

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17	I am able to make a personal connection with students when teaching large classes	3	V = 1047, P = 0.60	H = 4.00, P = 0.40	H = 2.14, P = 0.71	H = 0.29, P = 0.59	H = 4.61, P = 0.03
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