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Breaking the Binary: Teaching Inclusive Conceptions of Sex and Gender in Undergraduate Science

ABSTRACT

The need to make higher education curricula gender-inclusive is increasingly pressing as student cohorts diversify. We adopted a student-staff partnership approach to design, integrate, and evaluate a module that taught first-year science students the difference between biological sex, gender identity, gender expression, and sexual orientation in the context of genetics concepts at an Australian university. This module aimed to break the binary in misconceptions of both sex and gender, emphasising that both exist on separate spectra. Data triangulation was used to evaluate students' attitudes towards the module and their learning of module concepts. Students' attitudes were positive overall, and evaluation of students' learning indicated that the majority of students understood and retained key concepts, while also identifying common misconceptions. Perhaps the most important finding was that students who identified as belonging to a minority group had significantly more positive attitudes towards the module than non-minority students. This finding supports previous research that has found inclusive curricula have greater benefit for students from minority backgrounds, indicating the importance of making such curriculum enhancements. Our results speak to both the co-creation process and students' learning outcomes, providing valuable insights for practitioners both within science and beyond.

KEYWORDS

gender, undergraduate, biology, inclusion

INTRODUCTION

Felten et al. (2013, 63) argued: "Inclusive engagement has tremendous potential to enhance student and faculty learning, to deepen scholarship of Teaching & Learning (SoTL) initiatives, and to help redress the exclusionary practices that too often occur in higher education." This is the aspiration to which our study responds, not only in the process, but also the output of our initiative, which integrated diverse conceptions of gender and sex into undergraduate science curricula. We undertook this process with the aim of redressing exclusionary curricula that wrongly perpetuate outdated notions of binarised sex and gender in biology classrooms—a problem brought to our attention initially by our student partner in this initiative who described

> *LGBTQ+ people should never be expected to advocate alone, for their own rights, while also struggling with institutionalised discrimination and social ostracism. It is my hope that the work I have contributed to this project will alleviate at least a few of the many difficulties transgender and non-binary students face while studying. Ideally, it will be easier for them to go on and advocate for themselves in the future.*

It was with this aim that we—two teaching staff, an academic developer, and an undergraduate student—shaped our study to focus on the "what works?" domain of Hutchings's (2000) taxonomy of SoTL questions, specifically in relation to how undergraduate biology can be taught in gender inclusive ways. We were guided by Felten's (2013, 121) principles of good practice in SoTL such that we: (1) inquired into undergraduate students' learning about non-binarized conceptions of sex and gender in a first-year biology subject; (2) grounded our work in the geo-sociocultural context of our large public Australian university and the context of previous work in relevant literatures; (3) used sound methodologies by triangulating data from multiple sources, including student perspectives, grades, and analysis of assessment artefacts; and (4) conducted the design of our teaching intervention and the evaluation methods in partnership with a student who has a vested interest and relevant lived experiences in the teaching context and subject matter. And lastly (5), we now make our work appropriately public by sharing our findings with the broader SoTL community in the hopes that others both within and beyond science may find insight and confidence to undertake similar initiatives.

Teaching socially responsible biology in higher education

Biology is a broad subject for students to learn, interconnecting diverse concepts and theories (Wandersee, Fisher, and Moody 2000). Genetics is one of the most challenging topics, requiring a coherent understanding of events that occur at different biological organisational levels (Chi-Yan and Treagust 2004). For example, students need to understand events at the molecular (DNA) to micro (chromosomes) to macro (organismal) levels and relate those to biological processes that may not be directly observable.

The traditional accepted mode of instruction in universities for teaching genetics is primarily by lectures and practicals that rely on directing students to a recommended textbook. Whilst "straight from the book" instructional practices (Seymour and Hewitt 2000; Smith and Wood 2016) allow students to learn the foundational knowledge, continual developments mean this content lags years behind current genetic understanding, as well as behind contemporary discourses in society that influence and are influenced by how people engage with and conduct scientific research. The latter, regarding the sociocultural context of science and genetics, is often entirely excluded, leaving these scientific concepts divorced from reality and implicitly (and incorrectly) communicating to students that science happens in a social and political vacuum. In this way, developing the social responsibility of future scientists is often an overlooked and undervalued area in traditional science curricula (Schultz 2014).

A foundational concept in genetics is the role of sex chromosomes in determining biological sex and the development of male and female physical characteristics. This is often inaccurately taught, adhering to outdated understandings, i.e., that to be male you must inherit XY chromosomes or to be female XX chromosomes. This has led many to believe that biological sex is binary. Research has since demonstrated that biological sex is not binary but exists on a spectrum. For example, individuals can inherit an extra sex chromosome (e.g., XXY) and the genetics of intersex individuals is being increasingly understood. Further, despite a large body of psychology research reporting that gender identity exists as a spectrum and is a social construct distinct from biological sex (Hyde et al. 2019), views that conflate biological sex and gender identity and maintain that gender/sex are both/either binary are pervasive in both science and society (Korolczuk and Graff 2018). These were the conceptions that were taught in our core undergraduate biology unit taken by all science students until our student partner, author Arthur Morphett, highlighted the inaccurate and harmful nature of such teachings. We thus asked ourselves, "What can we do to teach the theory of genetics in ways that accurately reflect critical changes to the field based on evolving research?" How can our science curricula be more inclusive of diverse students and more accurately reflect changes in modern society?

The need for (gender-)inclusive curricula

We sought to take an inclusive curriculum approach to address our aim of accurately teaching genetics in relation to real-world contexts. Such approaches are critical given that student cohorts in higher education are rapidly diversifying in an era of internationalisation. This is signified by proportional increases in students from minority groups including those defined by race, gender, sexual orientation, religion, family composition, age, and economic status (Higher Education Today 2018). Barriers faced by such students are inequitable with students from minority groups facing greater challenges than their "traditional" counterparts in achieving academic success (Kuh, O'Donnell, and Schneider 2017).

One reason cited for these educational inequalities is the normative nature of curricula. Such curricula reflect the overrepresentation of staff from non-minority backgrounds who make decisions about syllabi as being predominantly white, cis-gendered, heteronormative, and patriarchal (Jester 2018), as well as the failure of curriculum revision and reform to keep pace with social change. Regarding student learning and engagement, seeing the omission of their histories and identities from mainstream curricula can lead to feelings of isolation, alienation, and marginalisation, to higher attrition rates, and to increases in inequitable sociodemographic attainment gaps (Abou El Magd 2016; Seidman 2012; Strayhorn 2012).

Making curricula more inclusive and representative of diverse identities—including gender identities—is an increasingly important area of research. Much work done in this space comes from the arts, humanities, and social sciences (Snapp et al. 2015) with less published in Australian STEM contexts. There are, however, notable exceptions indicating precedent and, given the under-representation of historically marginalised groups in STEM (e.g., Johnson et al. 2019), an urgent need for the implementation and evaluation of such initiatives in Australian science higher education. We, therefore, sought to teach genetics in undergraduate science incorporating non-binarized concepts of biological sex and gender identity, such that students from diverse backgrounds could see themselves reflected in their science curriculum.

Inclusive conceptions of gender in science curricula

For the purposes of this study, we explicitly define the difference between sex and gender as the former constituting the biological sex assigned at birth based on medical examination of a baby's physiological sex traits (e.g., genitalia, gonads, chromosomes most often determined to be "male," "female," or "intersex"), which we acknowledge to hold a harmful medicalised and discriminatory history for many people. We understand gender as a social and psychological construct of how an individual self-identifies on a wide spectrum of diverse gender identities. A person's gender identity may or may not align with the sex they were assigned at birth and the latter does not dictate the former. How a person expresses their gender identity through appearance is termed gender expression.

Many suggested strategies for creating gender-inclusive, tertiary curricula lay outside the content and learning objectives of an undergraduate science degree. Such approaches include using memoirs or film representations of nonbinary people as a pedagogical tool to encourage critical discourse analysis, which aims to expand student understanding of gender identities (Nicolazzo 2014a, 2014b). Approaching gender as an analytical construct as opposed to a descriptive category within political science curricula emphasises the importance of gender in understanding social issues and the effectiveness of the related policies which aim to help those affected (Cassese et al. 2012).

In Australian science tertiary education, the main focus of gender inclusivity is to address the gender polarisation between the physical and biological sciences, which are dominated by men and women respectively at the undergraduate level (Carrington and Pratt 2003). Despite this, there is still a lack of gender-inclusive curriculum in Australian STEM programs (Koppi, Roberts, and Naghdy 2012).

However, undergraduate biology subjects are in an unparalleled position to incorporate curricula that explains the concepts of biological sex and gender beyond the binary of the traditionally taught cis heteronormative male/female framework (Hughes 2001). This is due to the advancements in scientific research, which has begun to uncover the vast complexity in biological sex determination and gender identity (Hassold and Hunt 2001; Luders et al. 2009; Passarge 1995; Rametti et al. 2011; Wood 2013). Although developed for secondary school educators, gender-inclusive frameworks that could be adapted have been suggested for undergraduate science curricula, which encourage student engagement and create a safe, inclusive, and student-centric learning environment (Dare et al. 2017; Long 2019).

As the acceptance of diversity in biological sex and gender in society progresses (Australian Government 2013), including this content not only represents the modern scientific outlook, but also represents socially and culturally relevant pedagogical practises (Ladson-Billings 1995), which in turn increases the accessibility of the content to people of all genders (Driver et al. 1996).

The current study

We aimed to enhance and update the curriculum of a large, first-year biology subject to remove outdated and binarized terminology and concepts, and to integrate inclusive representations of sex and gender, relevant to the subject area of cell biology and genetics in a generalist bachelor of science degree programme. We drew on social psychological concepts to develop the gender-inclusive content that was integrated into the discipline of science. We used a novel pedagogical approach to update our curriculum—specifically, student-staff partnership—but this co-creation was not the focus of our evaluation in this study given that the benefits and challenges of such pedagogical approaches are increasingly well understood in the SoTL sphere (although we do return to this to reflect on the process in our discussion). Instead, we aimed to understand students' learning of and attitudes towards the novel concepts in the context of science taught via a module which was the output of the co-creation process. We explored the following questions:

1. What concepts from the module on sex and gender did students understand?
2. What concepts from the module on sex and gender did students misunderstand?
3. Did learning differ by gender, minority status, or student status (international/domestic)?

4. What were students' attitudes towards the module on sex and gender?
5. Did attitudes differ by gender, minority status, or student status (international/domestic)? The focus on differences by gender, student status, and minority status were chosen as they are directly relevant to the study focus of inclusive science curricula.

METHODS

Institutional context

This study occurred in a large university ranked within the top 10 Australian universities. In 2019, a total of ~27,000 undergraduate students were enrolled at University of Technology Sydney (UTS), ~13 percent (3,600) of whom were enrolled within the faculty of science. Cell biology and genetics (CBG) is a core subject, meaning it is taken by all students enrolled in the science degree. The teaching intervention and the data presented in this paper was from one of the two semesters in 2019 with a cohort of 292 students. Of these students, 58 percent were female and 6 percent were international students. As the survey was anonymous, we were not able to link the demographic characteristics of those who took the questionnaire to enrolment details. Ethics approval for this research was granted through the university's Human Research Ethics Committee (ETH19-3768).

Co-creating the module in partnership

The Sex vs. Gender Module (herein, "the module") was co-created by a partnership team of three academic staff members (the subject coordinator of CBG, a lecturer in CBG, and an academic developer) and one second-year undergraduate science student who had previously taken the subject, adopting a student-staff partnership approach. Partnership and co-creation of curricula are increasingly popular approaches in higher education which acknowledge that students and staff have unique and relevant, but distinct, expertise and experiences to bring to curriculum design (Cook-Sather, Bovill, and Felten 2014). The partnership team included one staff member who identifies as a cis-gendered queer woman and a student who identifies as transgender, along with two cis-gendered heterosexual women. Engaging students (and staff) from diverse backgrounds has been identified as a critical step to enhance the inclusivity of SoTL work (Felten et al. 2013). Ensuring people with relevant lived experiences working in partnership with allies was seen by the partnership team to be a critically important aspect of the design and research process, as we discuss later in this article.

The partnership team started by reviewing the content in the pre-existing lecture on the genetics of sex and identified places where problematic language needed to be reframed. These included, for example, removing harmful medicalized descriptions of intersex people and removing anthropocentric gendered language from inheritance descriptions, e.g., replacing *"Fathers* pass their X-linked alleles to all *daughters,"* which includes gender-specific language with *"Males* pass their X-linked alleles to all-*female* offspring," which relies solely on biological sex descriptors. We then created evidence-based content about biological sex, gender expression, gender identity, and sexual orientation supported by a list of relevant terminology with definitions for teaching staff (appendix A), integrating genetics content about the biology of sex. Students' learning of module content was assessed by a quiz that was also co-created by the partnership team (appendix B).

The sex vs. gender module

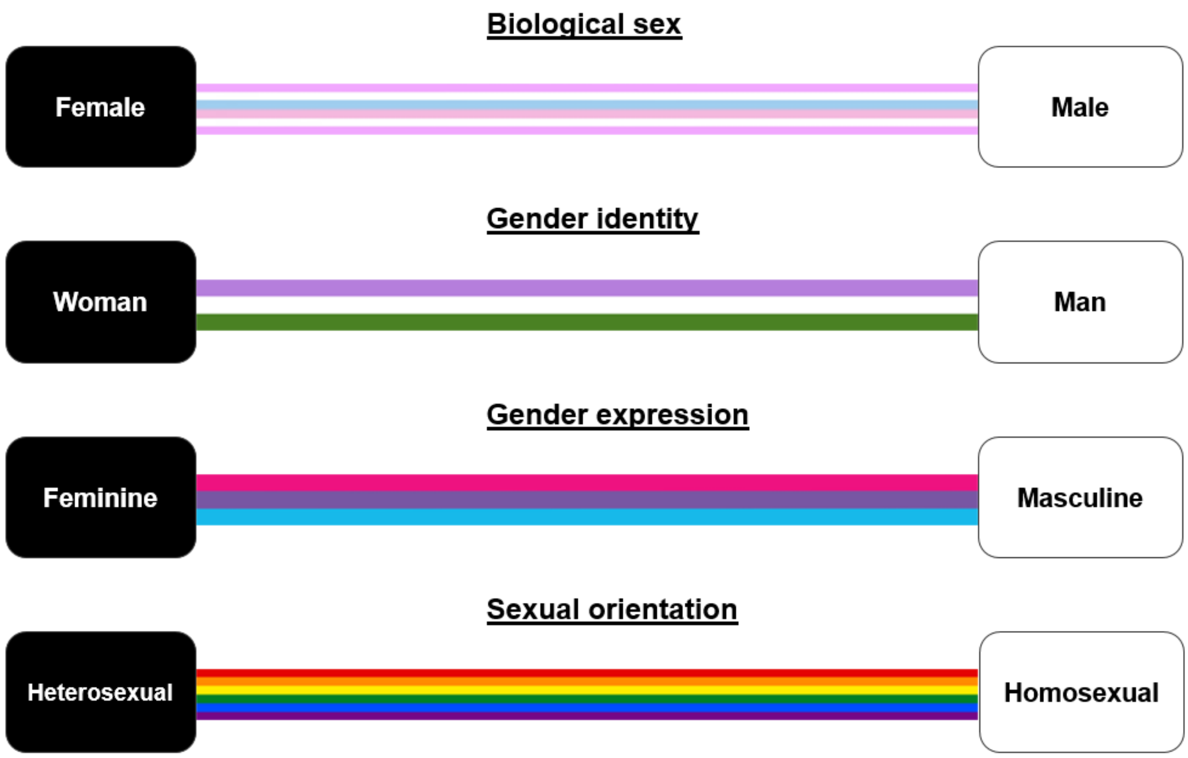
The lecture

The 20-minute module was delivered within a 90-minute lecture covering introductory genetics concepts. The module covered the following:

- Biological sex and gender identity are distinct constructs;
- Biological sex as a continuum that includes intersex individuals and the mechanisms; that cause non-bimodal distribution or changes in the sequence of sex chromosomes;
- Gender identity being a personal sense of one's own gender, which can be fluid and is not a binary, as a social construct that is distinct from biological sex;
- Gender expression being how a person outwardly shows their gender identity as a concept distinct from sex including personal pronouns; and
- Sexual orientation as defined by the gender or genders to which they are sexually attracted, a concept distinct from sex, gender identity, and gender expression.

The lecture emphasised that all these concepts are not binaries, and each occurs on a separate spectrum, which was illustrated using figure 1.

Figure 1. Summary of concepts taught in the gender-inclusive modules depicted as distinct spectrums as included in the lecture



The quiz

To assess what the students learnt from the module, students individually completed a quiz (appendix B) in their practical class, one week after the lecture. The quiz was worth 3 percent of the whole subject mark as one of a series of low stakes in-class quizzes. The tutors leading the practical were given the list of relevant terminology with definitions (appendix A) should students have any questions during the assessment. The assessment for the subject included practical reports/quizzes (35 percent), a scientific poster (25 percent), and a final examination (40 percent).

Evaluating CBG students' attitudes

Students voluntarily completed an anonymous online questionnaire to measure attitudes towards the module using Likert-scale and open response questions (table 1). The survey was newly created for this study, using items adapted from scales by Varsavsky, Matthews, and Hodgson (2013), and Kember and Ginns (2012). The survey items explored topics such as perceived understanding of the concepts introduced in the module, perceived usefulness of these concepts, and the desire for similar content to be included in other university courses. Demographic information was also collected, including age, gender identity, student status as domestic or international, and self-identification as belonging to a minority group.

Table 1. Items in the online student questionnaire

Item
Open response questions
What were the key concepts you learned in this module about biological sex and gender?
What, if anything, was challenging for you?
Do you have any other comments or feedback you would like to add about this module?
Quantitative items (*To what extent do you agree with the following statements*)
I feel confident that I understand these concepts.
Learning about these concepts is important in my science degree.
I found learning about these concepts interesting.
Learning about these concepts helped make science content more relevant to me.
These concepts will be useful to me in my future studies.
Other subjects in my degree regularly include links between the science taught and broader issues faced by society.
Learning about these concepts helped me to develop new perspectives.

Table 1. Items in the online student questionnaire

These concepts will be useful to me in my future studies.
Other subjects in my degree regularly include links between the science taught and broader issues faced by society.
Learning about these concepts helped me to develop new perspectives.
These concepts will be useful to me in my life outside the university.
I found learning about these concepts engaging.
The inclusion of these concepts improved my sense of belonging in science
Learning about these concepts helped me to gain a better understanding of myself.
Linking the science to broader issues faced by society is relevant to my degree.
I would discuss these concepts with my friends.
More concepts like this should be included in science degrees.
Learning about these concepts has made me more socially responsible.

Evaluating CBG students' learning

Multiple data sources were used to triangulate students' learning. Content-related quiz answers underwent thematic analysis to identify common areas of well-understood material and misconceptions. Students' responses to the question "What were the key concepts you learned in this module about biological sex and gender?" in the evaluation questionnaire (table 1) were analysed to evaluate what concepts students were able to retain and explain. Students' grades from the quiz and from the subject overall were compared. Finally, these data are triangulated with students' self-reported confidence in understanding the material in the quantitative questionnaire item "I feel confident that I understand these concepts."

Analysis

Qualitative data underwent thematic analysis using NVivo according to Braun and Clarke's (2006) six-phase approach involving iterative cycles of reading, coding, defining, and summarising data into themes and subthemes. An inductive, data-driven approach to analysis was adopted, meaning the themes and subthemes were based on what existed in the data rather than by applying a predefined coding framework. For the analysis of assessment tasks, students' answers on open response test questions were analysed for factual and conceptual accuracy by comparing responses to the taught content of the model and categorising text as whether the concept was understood or misconceived. For students' responses to the attitudinal questionnaire, open response comments were grouped by emergent themes in alignment with each question. In both cases, test references within each theme or subtheme were counted to generate quasi-quantitative count data, allowing us to speak to the frequency with which themes existed in the data. Quantitative data were analysed using R (R Core Team 2019) and RStudio (RStudio Team 2015). We conducted exploratory factor analysis to investigate the psychometric structure of the 15-item quantitative scale.

RESULTS

Results are separated into two sections, "student learning" and "student attitudes," each of which draws on multiple sources of data. Where qualitative responses were substantive, the text was coded into multiple themes, meaning that the total number of text references in count data for themes will exceed the total number of respondents.

Student learning

Self-reported learning

In total, 121 of 292 students (41 percent) responded to the questionnaire; sample sizes vary for questions as not all respondents answered all questions. Two questions on the student attitudinal questionnaire pertained to the evaluation of student learning. Students reported their self-perceived confidence in their learning on the quantitative Likert-scale question, "I feel confident that I understand these concepts." The majority (85 percent, n = 100) of respondents for that item (n = 118) reported that they agreed or strongly agreed with the statement (mean = 4.07/5).

Students were also asked, "What were the key concepts you learned in this module about biological sex and gender?" to evaluate what students had retained. In total, 102 answered (84 percent); these responses constituted 122 separately coded text references that were categorised into eight themes shown (table 2). Themes are sorted by prevalence indicating which concepts were most commonly retained. Students seemed to grasp that there is a difference between biological sex and gender, what that difference is, and that neither is binary. These results align with the analysis of assessment tasks below (table 3).

Table 2. Themes representing key concepts students reported they learned with indicative quotes and counts of text references

Theme	Description	Indicative quotes	Reference count
Biological sex and gender are different	Stated that the concepts were different, but did not explain how	"There is a distinct difference between sex and gender, and they are both complex and multi-faceted topics."	41
Variability in sex chromosomes	Described concepts relating to sex chromosomes, including mosaicism, chimerism, intersex, etc., and resulting physiology	"Biological sex is the separate of male, female and intersex through the variability in size or composition of gonads, genital morphology, chromosomes and/or hormonal physiology."	27
Difference between biological sex and gender	Explained the difference between sex and gender	"Biological sex is defined as the sex we're are assigned at birth, whilst gender is the personal sense of one's identity due to personal belief and society norms."	22

Sex is non-binary/fluid	Stated that biological sex was non-binary, could change, or was on a spectrum	"Biological sex is a spectrum not a binary; there are many different sex chromosome combinations that affect the sex of a person."	21
Gender is non-binary/fluid	Stated that gender was non-binary, could change, or was on a spectrum	"Sex and gender are different, and both exist on a spectrum as opposed to one fixed label."	16
Gender is a social construct	Stated that gender was a social construct	"Biological sex refers to an individual's chromosome arrangement, physical genitalia, and reproductive system, whereas gender identity is a social construct."	15
Other		"Nothing I didn't already know."	6
Broader implications	Described broader implication of the module	"What a binary is, and how it affects those that do not identify with either presented in society; how gender and identity affect how scientific research is conducted."	3

Assessment task analysis

Analysis of quiz answers identified main themes with sub-themes indicating where students understood or had misconceptions about content (table 3). Overall, 181 quizzes (62 percent) were able to be collected for analysis. Student assessment tasks showed more students understood the core concepts of the module than not and usefully identified common misconceptions. The below sections expand on conceptual understanding and misconceptions with summary statistics calculated using the number of collected quizzes (n = 181).

Table 3. Conceptual understandings and misconceptions in student quiz responses

Theme	Subtheme	Description	Indicative quotes	Reference count
Biological sex	Understanding	Determined by chromosome arrangement, physical genitalia, and reproductive organs	"Biological sex—chromosome arrangement, physical genitalia and reproductive system"	47
		Can change over lifetime	"Aspects of a person's biological sex can change through treatments such as hormone therapy" "Aspects of a person's biological sex can change as phenotypic characteristics can be altered as well as hormone levels through medical intervention"	105

	Misconception	Biological sex cannot change over a lifetime	"You cannot biologically change a person's sex as you'd have to change the chromosome makeup" "Biological sex cannot change, but physical aspects can change to suit gender identity" "Biological sex cannot change as it was assigned at birth" ". . . cannot naturally change their biological sex"	41
Sex is not a binary	Understanding	Range of chromosome complements, hormone levels, and phenotypic variations in primary and secondary sex characteristics	"Sex is not a binary due to a range of chromosome complements, as well as a range of sex hormone levels and range of phenotypic variations in primary and secondary sex characteristics"	104
		Is a spectrum	"Small proportion of the population is intersex—born with reproductive or sexual anatomy that do not fit in with the medical and social norms for male and female" " . . . some individuals acquire different sex attributes (such as intersex) outside of the binary . . . in addition to the fact that there is no single measure defining each sex, it cannot be considered as binary."	19
	Misconceptions	Is either male or female	"Biological sex can be defined as either female or male and is determined by . . . genetic differences" "Biological sex is defined by chromosomes and determines male or female" "Biological [sex] is the separation of male and female through composition of gonads, genital morphology, chromosomes"	27
Genetics of intersex	Understanding	Chromosomal mosaicism of sex chromosomes with understanding of mechanism	"[Chromosomal mosaicism is] when an organism has two or more populations of cells with different genetic content which has developed from a single embryo. Can be caused by anaphase lag which is when sister chromatids do not separate as they're not tightly bound to spindle via kinetochore"	58

Gender identity	Understandings	Personal identity	"Gender identity: Cultural meanings attached to being masculine and feminine, which influences personal identities"	46
		Independent of biological sex	"Biological sex refers to chromosome arrangement, physical genitalia and the reproductive system, whereas . . . gender identity encompasses and broad and inclusive spectrum of genders which aren't based on biological identifiers"	61
	Misconceptions	Conflated with gender and/or gender expression	"Gender identity is defined by society and their views" "Gender identity is socially created characteristics such as gender expression"	53
		Influenced by biological sex	"[Gender identity is] influenced by social characteristics and biological sex"	8

Concept: Biological sex is not fixed

The majority of students (58 percent, n = 105) articulated that biological sex is not fixed over a person's lifetime and many provided examples of how this change may occur. However, a proportion of students (23 percent, n = 41) stated inaccurately that biological sex could not change, with many arguing that as a person's chromosomes were fixed throughout a person's lifetime, therefore so is biological sex. This was counter to the taught content that discussed biological sex as being defined by multiple factors, all but one of which could change across a lifetime.

Concept: Genetic mechanisms that contribute to intersex

One third (32 percent, n = 58) provided a detailed description of a molecular mechanism that causes genetic differences that lead to intersex variations. This suggests that these students have re-framed and expanded prior knowledges and teachings, in this case about chromosomal segregation during cell division, to incorporate new concepts included in the module. Students who inaccurately answered this question did not share a common theme of misunderstanding the content.

Concept: Gender identity

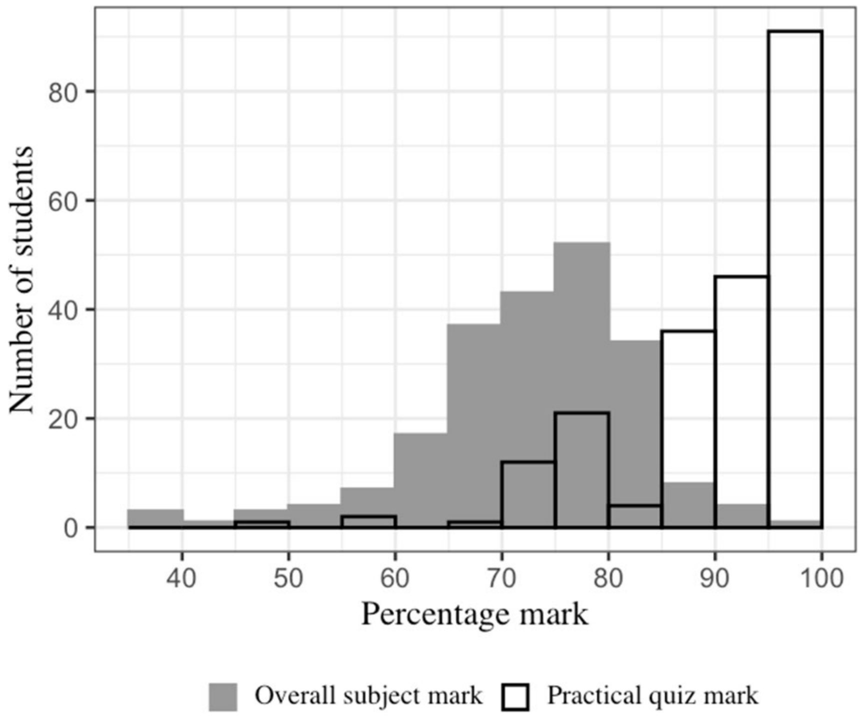
One quarter of the students (25 percent, n = 46) understood that gender identity is a personal identity that describes how individuals experience their gender. However, a greater proportion of the students (29 percent, n = 53) had confused gender identity with another concept, commonly societal expectations of gender and gender roles, or gender expression.

Analysis of the student responses to the worksheet questions demonstrates that there was considerable engagement with, and understanding of, the content. Furthermore, it highlighted concepts that require further clarity, such as gender identity.

Grades distribution

Seventy-three percent of students in the class (n = 214) took the quiz, with an average achievement of 91 percent (12.76/14). There was a small to medium correlation between the quiz and final marks (*rho* = .19, *p* = .005): students who did better on the module quiz tended to receive a better overall mark as well. The average quiz mark was significantly higher than the average overall mark, $t(213) = 22.40$, $p < 0.001$ (figure 2). This aligns with thematic analysis of quiz answers, indicating that students understood the content more commonly than not. We found no evidence of gender differences on the module mark ($t(171.17) = 0.58$, $p = .56$) or the overall mark ($t(184.55) = 1.27$, $p = .20$) and no differences between the marks achieved by domestic vs. international students: for the module mark, $t(43.65) = -0.22$, $p = .83$; for the overall mark, $t(38.81) = 0.77$, $p = .45$.

Figure 2. Distribution of marks for the practical quiz and overall subject (n = 214)



Student attitudes

Students who took the questionnaire (n = 121) were predominantly in the 18–29 years old bracket (97 percent, n = 117), with one student from the 30–39 bracket, one from the "over 80" bracket, and two under 18 years old. Most participants identified as female (63 percent, n = 76), with a substantial minority of males (35 percent, n = 42), two identifying as non-binary, and one who preferred not to disclose their gender. These demographic data are representative of the students enrolled in the CBG subject, who are also predominantly in the 18–29 age bracket and female. Twenty-five participants reported that they belonged to a minority group (21 percent), 10 percent were not sure (n = 12), and three preferred not to disclose. Most participants (67 percent, n = 81) reported not being from a minority group.

Quantitative items

Questionnaire structure

We used two methods to validate the questionnaire: internal consistency reliability and exploratory factor analysis. The Cronbach's alpha coefficient indicated high internal consistency reliability (a = .96). In the exploratory factor analysis, we found that all 15 items from the questionnaire loaded on a single factor, with factor loadings between .57 and .86, and the factor explained 62 percent of variance in the individual items. This means that all questionnaire items can be interpreted as strongly related to one single construct, attitude towards the module.

Following factor analysis, we calculated an average of participants' responses to the 15 closed-response items (table 1) to form a single attitude score. A higher score indicates a more positive attitude towards the module. This score was the outcome variable in the following quantitative analyses.

Attitudes towards the module

The overall attitude towards the module across all items was positive, with an average score of 3.44 (SD = 0.93) on a five-point scale. Mean and response distributions for individual items are shown in table 4. There was a statistically significant difference (t *(43.86)* = -2.55, p = .014) in attitude between students who reported belonging to a minority group and those who did not: on average, students with minority status had more positive attitudes to the module (M = 3.82, SD = 0.83), than those who did not (M = 3.32, SD = 0.92). There were no significant differences in attitudes between gender or age groups.

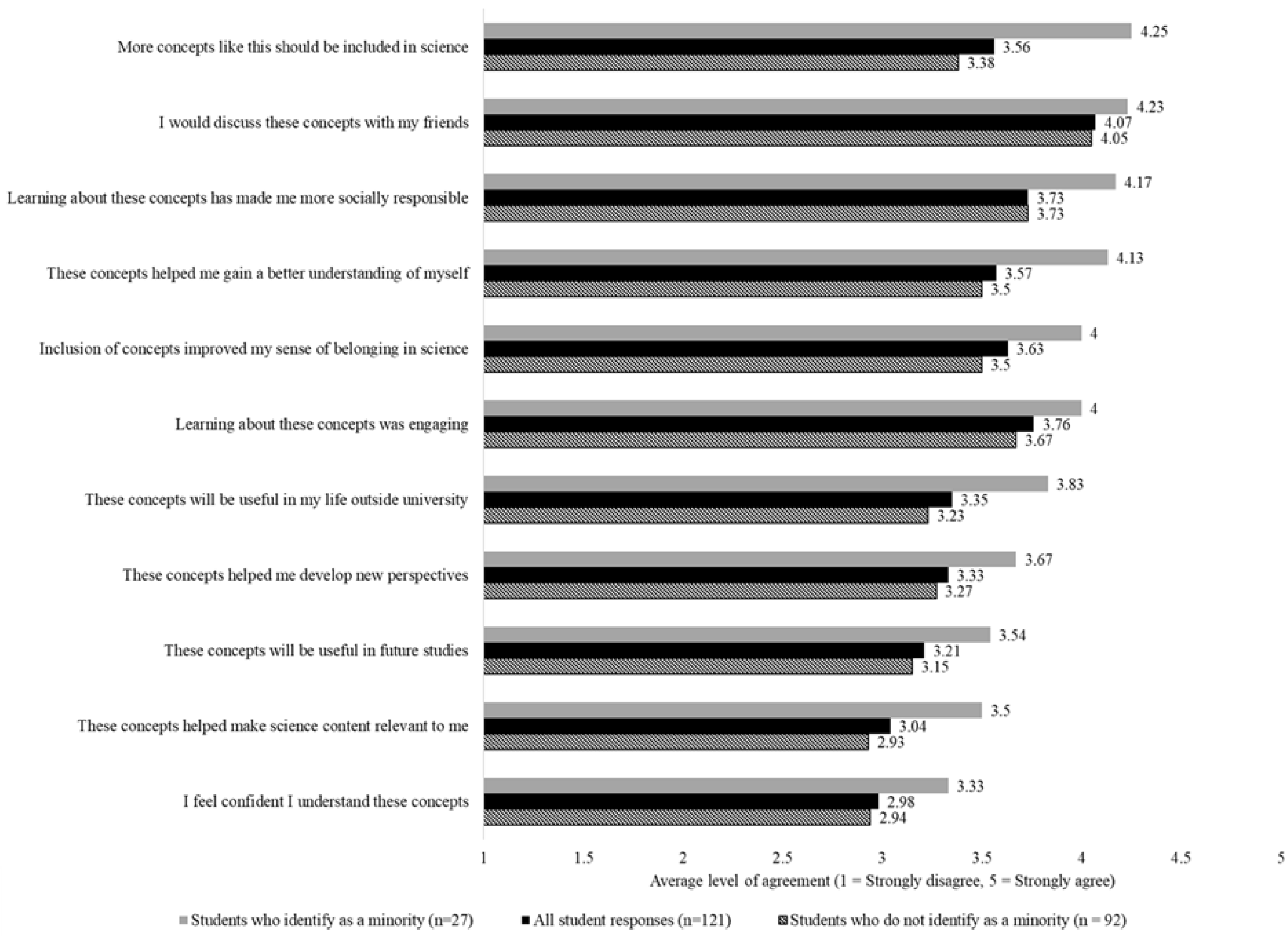
Table 4. Means and standard deviations for individual items

Item	Mean	SD	n
I feel confident that I understand these concepts.	4.07	0.90	118
Learning about these concepts is important in my science degree.	3.14	1.30	118
I found learning about these concepts interesting.	3.76	1.11	118
Learning about these concepts helped make science content more relevant to me.	3.27	1.28	118
These concepts will be useful to me in my future studies.	2.98	1.22	120
Other subjects in my degree regularly include links between the science taught and broader issues faced by society.	3.21	1.22	120
Learning about these concepts helped me to develop new perspectives.	3.33	1.11	120
These concepts will be useful to me in my life outside the university.	3.72	1.20	120
I found learning about these concepts engaging.	3.63	1.15	118
The inclusion of these concepts improved my sense of belonging in science.	2.95	1.17	120

Learning about these concepts helped me to gain a better understanding of myself.	3.04	1.10	120
Linking the science to broader issues faced by society is relevant to my degree.	3.57	1.20	119
I would discuss these concepts with my friends.	3.56	1.21	120
More concepts like this should be included in science degrees.	3.47	1.28	120
Learning about these concepts has made me more socially responsible.	3.35	1.17	119

Figure 3 shows a comparison of means for individual items for minority students, non-minority students, and for the whole sample. Due to the large number of items, we did not conduct statistical testing for each item separately, as that would inflate the rate of false positives. However, the means are presented in the figure to inform potential future research. Students from minority backgrounds responded more positively on every item as shown in figure 3. Full questionnaire items relating to short-hand descriptions in figure 3 are presented in table 1.

Figure 3. Mean responses for individual items for the full sample, students who identified as belonging to a minority group, and students who did not identify as belonging to a minority group



Qualitative items

Open response questions from the questionnaire (n = 121) are reported below by the following question:

What, if anything, was challenging for you?

Seventy-seven (64 percent) responded to this question with 47 giving responses similar to "Nothing was challenging," which reflects the assessment marks where the majority of students did well. Six responses were categorised as "Other" where comments were not pertinent to the study focus. Eight respondents' comments were coded as "Both sex and gender were challenging":

> *Whether all females have XX chromosomes. I didn't know in which context the question was asking . . . biological sex or gender identity.*

Four respondents found concepts relating to "Gender" challenging:

> *To understand why anyone can just choose what gender they want to be.*

Three stated that the content did not belong in a science subject:

> *I have absolutely no problem at all with the content of the lecture and prac*[tical]*, however I think it is completely unnecessary and wrong to be teaching it as science. People's gender identity has nothing to do with science and should be taught as a separate, electable subject.*

Four students disagreed with the content in the module, predominantly for political or beliefs-based reasons:

> *The concept of gender being unrelated to sex goes against my beliefs. I have believed and still do believe that there are only two genders and that sex determines gender as that is how we were made.*

Do you have any other comments or feedback you would like to add about this module?

Twenty-six students responded to this question for which substantive responses were coded into three themes. The first included 12 students giving positive feedback that predominantly addressed the importance of including this content in the subject, and a strong appreciation for content being presented in a scientific way:

> *It was great! Please keep this in the subject, I think it is great it is being taught in science subjects and great to teach future scientists who might not have known this previously.*

> *Very relevant and scientifically presented.*

> *It was a very useful and very appropriate module . . . It was taught in a scientific way, which is why I believe it will be successful.*

The second theme included negative comments from six students, predominantly based on the content being different from their beliefs:

> *Science is grounded on objective/fact-based reasoning. Therefore, it is best if politics/philosophy/personal beliefs are kept out of science. Teaching this module could also potentially marginalize science students who hold to different beliefs than to that of what is taught in this module.*

The final theme for this question included suggestions for enhancements including that the module should be integrated across the university, to have the module in a separate lecture, and to go into more depth on scientific studies.

DISCUSSION

The following sections discuss key themes, considerations, and implications across and arising from both the above data and our reflections as a partnership team. As with any evaluation of teaching in higher education, the experiences of researchers who are also teachers and designers of educational interventions provide unique "insider" perspectives (Hamdan 2009) on which we draw throughout the discussion. This provides fruitful insight, particularly in the final section, for colleagues who may wish to undertake future similar interventions.

Compensatory effects for students from minority backgrounds?

Inclusion in higher education and gender-inclusive science curricula has been a rapidly evolving discourse with previous research articulating various pedagogical approaches across contexts with a larger body of work addressing school education (e.g., Parker and Rennie 2010) than higher education (e.g., Koppi et al. 2010). An important finding from this study was that students who identified as coming from marginalised backgrounds had significantly more positive attitudes to the incorporation of gender-inclusive content than their counterparts. When we deconstruct the attitudinal scale into individual items, the biggest differences (0.5 or more on the Likert scale) for marginalised students were those with a desire to see more similar content in their science degree, relevance to life outside university, relevance to the degree, an increase in individual social responsibility, contributed to gaining a better understanding of themselves, an improved sense of belonging in science, and engagement with concepts (figure 3).

Research shows students from minority groups can face greater challenges than their "traditional" counterparts in achieving academic success (Kuh, O'Donnell, and Schneider 2017). As discussed in the introduction, the erasure of diversity from curricula is one of the foremost cited reasons for this disparity in outcomes. Our results indicate the potential beneficial impact of including more diverse representations of sex and gender in mainstream science curricula. Should such representation be integrated beyond a single subject (as in this case) to broader degree programmes, this increased sense of belonging, engagement, and relevance may be opportunities offered to a greater number of students from minority backgrounds. These aspects of learning contribute greatly to academic success and completion rates (Strayhorn 2012), allowing for a greater diversity of students continuing in science—a much needed change in a field which is currently facing a severe lack of diversity (Smith et al. 2015). Students in our study supported this suggestion giving feedback such as "to share this information to all students, not only people doing a science degree."

We argue that the effects found in our results are akin to those termed in educational literature as compensatory effects. Compensatory effects describe the notion that some learning activities, while advantageous for all students, can be extra-beneficial for students from minority backgrounds (Cruce 2006; Finley and McNair 2013). In our project, all students (on average) benefitted from learning more about the biological basis of sex and the more socially constructed nature of gender. For students from minority groups, this felt particularly relevant and contributed to a better understanding of themselves, potentially leading to an increased sense of belonging within their science degree. Teaching approaches that foster such compensatory effects are critical now more than ever as many higher education institutions are facing what has long been predicted to be a "new majority" of students (Rendon and Hope 1996). This new majority is becoming a reality (Miller, Valle, and Engle 2014) and curricula need to evolve in response to reflect, represent, and include *all* students—not just the historical "norm." Arguably, the approach of diversifying curricula to genuinely include and promote the success of students from minority backgrounds may be the most widely successful, given that other approaches which use extra- or co-curricular experiences often exclude students from minority backgrounds due to competing priorities and availability (Mercer-Mapstone and Bovill 2020).

A scientific approach was important

The gender-inclusive module was delivered by a different lecturer in a pre-existing, 90-minute lecture that introduced basic genetic concepts. To reduce the likelihood of the module being perceived by the students as “additional” or “tokenistic” content, we clearly linked the content to genetic concepts and mechanisms to appropriately contextualise the module and emphasize its relevance with respect to the learning outcomes of the lecture. Triangulating data across sources, as described below, gives us the insight that this scientific approach to teaching concepts was important for students’ learning.

Linking of the content to scientific concepts, however, was not consistent across the module. Concepts such as intersex were grounded in genetic mechanisms that influence the distribution, and therefore variability, of sex chromosomes in an individual. Student responses, as exemplified in above results, reflected that this scientific approach was appreciated.

However, explanations of other topics such as gender expression and sexual orientation lacked the same scientific evidence in the delivery. This discrepancy was due to our specific scientific expertise and time constraints. Furthermore, the lecturer who delivered the module was more comfortable teaching the data-driven section of the module and more anxious explaining topics such as gender. This apprehension stemmed from this being the first time delivering this content, concern at how the students would respond to the module, and fear of expressing the concepts poorly and perpetuating or supporting misconceptions or biases.

Students picked up on this—while the questionnaire showed 70 percent of the students agreed that the concepts introduced in the module will be useful to their life outside of university, 33 percent of the students did not think the module was important to include in a science degree. In contrast, 61 percent agreed that linking science to broader issues faced by society is relevant. When asked what was challenging about the content, student responses included “where to draw the line between what is biology and what is psychology or the study of society” and “I think it is great that the topics are being so openly talked about. I just didn’t know why some of the content was being included in a science subject.” This illustrates that some students struggled to understand the relevance of some of the content, which may be addressed in future iterations by ensuring that all the content in the module has firm scientific grounding. This approach may also help to combat perceptions that social constructs such as gender are non-scientific, political, or belief-based, which were expressed by a small number of students.

Due to the discrepancies in the amount of scientific data supporting the different topics, and the importance of perceived relevance to student comprehension (Belet 2018), we hypothesized that this variation may be reflected in student learning. The key concepts learnt from the module, as self-reported by the students (table 2), indicate that the most prevalent concept the students understood was that biological sex and gender are different (63 references). The lecturer was comfortable in delivering this concept and utilized a scientific definition of biological sex. The data-driven concepts such as biological sex and variability in sex chromosomes have a substantial number of self-reported student references (48 references), whereas topics discussed with a less scientific approach, such as gender being a social construct and gender expression, were less frequently identified as key concepts by students (31 references).

As expected from the student survey, students demonstrated understanding that gender identity was independent of biological sex in their assessment quiz (61 references). Many students could substantiate that biological sex was not a binary with appropriate genetic and physiological concepts (104 references). In contrast, gender identity was misconstrued by a larger number of students (53 references) than could accurately define the concept (46 references).

These data indicate that data-driven concepts were understood by a larger number of students when compared to the less scientifically substantiated topics. To clarify, the concepts themselves are not less scientifically substantiated, but were taught in a way which perhaps made them appear as such by integrating less of that research. This imbalance should be addressed in future iterations of the module. However, the appropriate scientific evidence goes beyond the scope of human genetics and therefore it may be appropriate to deliver this content as a separate lecture. This would also give students accurate expectations of the lecture, which may boost student satisfaction with the content (Appleton-Knapp and Krentler 2006). Alternatively, the content could be split and delivered in smaller segments throughout a subject or program as relevant to other content. A more systemic style of delivery may help to normalise these discussions within the curriculum.

The role of allies and partners in creating gender-inclusive curricula

The module was co-created with two teaching staff, a learning designer, and a student partner, who undertook an academic internship for credit, as well as receiving a small stipend to work on this curriculum intervention and is also a co-author on this paper. Our data indicate that this teaching intervention was a success on many fronts, and it is our belief and experience that this success would not have been possible without having taken such a partnership approach. In this section, we expand on and discuss two distinct perspectives on the module and elucidate that the role of "allies" was one which influenced our own experiences of undertaking this intervention powerfully. In doing so, we step beyond the realms of our data, which might be seen as an untraditional blurring of the boundaries of a scholarly article. We feel that this is both legitimate and necessary, however, given that we are "insiders" in the research process (Hamdan 2009) and thus our experiences cannot and should not be divorced from the findings as they were in fact central to the outcomes achieved. This kind of practitioner reflection, which extends or blurs the boundaries of traditional research, is indeed one of the reasons we embrace SoTL as a multidisciplinary home where blurring of boundaries is not only allowed but encouraged. Thus, the following two paragraphs are written from the perspective of two of our co-authors who had unique and critical roles in the process of co-creating, implementing, and evaluating this module. We hope that this integration of practitioner reflection on co-creation speaks to and encourages others to take such a similar partnered approach in future similar endeavours.

Author Arthur Morphett:

As far as I am aware, I am the only transgender student who worked on this project. It is clear that LGBTQ+ allies need to use their privilege to advocate for the community as well. The work I have produced would not have been possible without the help of such allies. Of the four people in our working group, I was the only transgender person, and there was only one other queer collaborator. The other two, despite their unfamiliarity with many LGBTQ+ issues, were still enthusiastic to work with us. Their allyship and willingness to make a positive change to the science curricula was invaluable. LGBTQ+ people should never be expected to advocate alone, for their own rights, while also struggling with institutionalised discrimination and social ostracism. It is my hope that the work I have contributed to the project will alleviate at least a few of the many difficulties transgender and non-binary students face while studying. Ideally, it will be easier for them to go on and advocate for themselves in the future.

Author Sarah Bajan:

As a cisgendered, heterosexual, white woman, I had reservations about delivering this module. I felt that because I could not relate to the content, and was initially ignorant of the concepts, I was under-qualified to discuss this with students. I was concerned that I would "say the wrong thing" and inadvertently reinforce pre-existing misconceptions or biases. These fears decreased during module creation. I attribute this to (i) completing LGBTQ+ ally training, (ii) the supportive working environment in which mistakes or knowledge gaps were not vilified and all team members were transparent regarding their learning journey with the content, and (iii) much of the created content specifically linked to human genetics, which I have experience teaching. Before this project, I considered myself an LGBTQ+ ally. However, this experience highlighted my silence, trepidation, and ignorance about concepts pertinent to LGBTQ+ student experiences. I realised that being an ally is not about demonstrating compassion, but about using my privilege to help create space for people with experiences different from my own. As an educator, I always regarded it my responsibility to reach each student, but never actively employed strategies to do so. I now understand that educators need to push beyond their comfort zones to discuss topics in which they are not expert and to have conversations with students so that their experiences become an essential component of the content narrative. Working with both staff and student partners has reinforced the importance of student contributions to developing inclusive curriculum, and why it is critical to effectively incorporate and normalise content that reflects the diversity of the student cohort.

The above paragraphs emphasise two themes. The first is that the role of allies in creating gender-inclusive curricula is critical in both sharing the burden of risk-taking and to the success of such initiatives. The second theme is that the pedagogical approach of student-staff partnership and co-creation allowed us to create brave spaces (Arao and Clemens 2013) where students and staff can make mistakes and learn from each other, drawing on their own experiential and disciplinary expertise (Cook-Sather 2016). In this latter way, students and staff acted as allies for each other beyond the LGBQIA+-specific meaning of the word, to offer support and encouragement as we undertook this risky and emotionally laborious work. Speaking to SoTL practitioners more broadly, we therefore find it important to encourage not only the inclusion of diverse students in SoTL work (Felten et al. 2013), but also to seek the involvement of staff with diverse lived experiences so that curricula do not continue to remain solely in the hands of the institutional norm. Pedagogical partnership is complex and messy as power dynamics are inherently at play (Mercer-Mapstone and Mercer 2017), but we found that this approach enabled us to co-create a teaching intervention that we believe was authentic to our (and perhaps others') diverse lived experiences.

Limitations

There are limitations to this study that readers should consider when interpreting findings. The first was a choice made to depict biological sex, gender identity, gender expression, and sexual orientation as spectra (figure 1). Using a visual spectrum to show that, for example, biological sex ranges between male and female with multiple possibilities in between was a visually useful way to depict fluidity. However, a spectrum has two distinct endpoints that may unintentionally reinforce the binaries we were trying to break. This limitation was verbally communicated in the lecture, but there still exists the risk that the message was counter to our aims.

The second limitation was that the module was delivered in a traditional lecture. This was done in an effort to be congruent with the predominant teaching approach in this subject. Active learning and structured reflection are known, however, to best facilitate the learning of this kind of potentially challenging content (Curry-Stevens 2003) and future initiatives should aim to integrate such approaches. This is a particularly important consideration in light of recent research showing that active learning can narrow achievement gaps for underrepresented students in undergraduate science (Theobald et al. 2020).

In quantitative analyses, we were limited by not being able to attribute the questionnaire responses to individual students and their marks. This was done to maintain anonymity; however, had we been able to link them, an in-depth analysis of students' attitudes towards the module related to their marks could have been explored. Another limitation was the cross-sectional nature of this study: as we only gathered data after the module, we were not able to compare students' attitudes and knowledge before and after taking the module. In the future, this could be remedied by adopting a longitudinal design.

CONCLUSION

Inclusive curricula are important for all classrooms. Regardless of discipline and location, we believe all educators will find something of value in this study—from the inclusive co-creation process used to make curricula more gender-inclusive to the results themselves that speak to students learning and attitudes towards gender-inclusive content. Key results showed that students were more likely to understand and retain knowledge of concepts if they were taught scientifically, indicating that embedding such gender-inclusive content within the norms of the home discipline is likely to be critical for the effective learning of these potentially new concepts. Students from minority backgrounds perceived the content more positively than their non-minority counterparts suggesting some level of compensatory effect, although on average student perceptions were positive overall. This was an important finding indicating that including inclusive and socially progressive content in traditional degrees can increase the engagement of and sense of belonging for those students who are traditionally excluded in higher education environments. We believe the pedagogical approach of having students and staff from both LGBTQIA+ and heterosexual identities working in partnership to create the content was likely to have been critical to these experiences, in working to create content that authentically represented a diversity of lived experiences. The development and expansion of gender-inclusive curricula, particularly in male-dominated heteronormative fields like science, is critical at times when student cohorts are rapidly diversifying and sectors are still facing gender imbalances. We hope the teaching intervention shared here and the promising results encourage other educators to undertake similar curriculum inclusion efforts within science and beyond.

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REFERENCES

Abou El Magd, Noha 2016. "Why is My Curriculum White?—Decolonising the Academy." National Union of Students. https://www.nusconnect.org.uk/articles/why-is-my-curriculum-white-decolonising-the-academy.

Appleton-Knapp, Sara L., and Kathleen A. Krentler. 2006. "Measuring Student Expectations and Their Effects on Satisfaction: The Importance of Managing Student Expectations." *Journal of Marketing Education* 28, no. 3: 254–64. https://doi.org/10.1177/0273475306293359.

Arao, Brian, and Kristi Clemens. 2013. "From Safe Spaces to Brave Spaces: A New Way to Frame Dialogue Around Diversity and Social Justice." In *The Art of Effective Facilitation: Reflections From Social Justice Educators*, edited by L. M. Landreman, 135–50. Virginia: Stylus Publishing.

Australian Government. 2013. Australian Government Guidelines on the Recognition of Sex and Gender. 1–11. https://www.ag.gov.au/Publications/Pages/AustralianGovernmentGuidelinesontheRecognitionofSexandGender.aspx.

Belet, Margot. 2018. "The Importance of Relevance to Student Lives: The Impact of Content and Media in Introduction to Sociology." *Teaching Sociology* 46, no. 3: 208–24. https://doi.org/10.1177/0092055x17730113.

Braun, Virginia, and Victoria Clarke. 2006. "Using Thematic Analysis in Psychology." *Qualitative Research in Psychology* 3, no. 2: 77–101. http://dx.doi.org/10.1191/1478088706qp063oa.

Carrington, Kerry, and Angela Pratt,. 2003. "How Far Have We Come?: Gender Disparities in the Australian Higher Education System." Department of the Parliamentary Library Canberra, 31.

Cassese, Erin. C., Angela L. Bos, and Lauren E. Duncan, 2012. "Integrating Gender into the Political Science Core Curriculum." *PS:—Political Science and Politics.* 45, no. 2: 238–43.

Chi-Yan, Tsui, and David F. Treagust. 2004. "Motivational Aspects of Learning Genetics with Interactive Multimedia." *The American Biology Teacher* 66, no. 4: 277–85. https://doi.org/10.2307/4451670.

Cook-Sather, Alison, Catherine Bovill, and Peter Felten. 2014. "Engaging Students as Partners in Learning and Teaching: A Guide for Faculty." Edited by Maryellen Weimer. San Francisco, CA: Josey-Bass.

Cook-Sather, Alison. 2016. "Creating Brave Spaces within and through Student-Faculty Pedagogical Partnerships." *Teaching & Learning Together in Higher Education* 18.

Cruce, Ty M., Gregory C. Wolniak, Tricia A. Seifert, and Ernest T. Pascarella. 2006. "Impacts of Good Practices on Cognitive Development, Learning Orientations, and Graduate Degree Plans During the First Year of College." *Journal of College Student Development* 47, no. 4: 365–83. https://doi.org/10.1353/csd.2006.0042.

Curry-Stevens, Ann. 2003. "An Educator's Guide for Changing the World: Methods, Models and Materials for Anti-Oppression and Social Justice Workshops." Center for Social Justice. http://www.socialjustice.org/uploads/pubs/EducatorsGuideforChangingtheWorld.pdf.

Dare, Emily, Dave Rafferty, Elizabeth Scheidel, and Gillian Roehrig. 2017. "Flood Rescue: A Gender-Inclusive Integrated STEM Curriculum Unit." *K-12 STEM Education,* 3, no. 2: 193–203.

Driver, Rosalind, John Learch, Robin Millar, and Phil Scott, 1996. *Young People's Images of Science.* Buckingham: Open University Press.

Felten, Peter, Julianne Bagg, Michael Bumbry, Jennifer Hill, Karen Hornsby, Maria Pratt and Saranne Weller. 2013. "A Call for Expanding Inclusive Student Engagement in SoTL." *Teaching & Learning Inquiry* 1, no. 2: 63–74.

Felten, Peter. 2013. "Principles of Good Practice in SoTL." *Teaching & Learning Inquiry,* 1, no. 1: 121–25.

Finley, Ashley, and Tia McNair. 2013. Assessing Underserved Students' Engagement in High-Impact Practices. In *Association of American Colleges and Universities*. Washington, DC: Association of American Colleges and Universities.

Fisher, Kathleen. M., James H. Wandersee, and David E. Moody, 2000. "The Nature of Biology Knowledge." In K. M. Fisher, J. H. Wandersee, and D. E. Moody (Eds.), *Mapping Biology Knowledge*. New York, NY: Springer Netherlands. 25–38.

Hamdan, Amani K. 2009. "Reflexivity of Discomfort in Insider-Outsider Educational Research." *McGill Journal of Education*, 44, no. 3, 377-404. https://doi.org/10.7202/039946ar.

Hassold, Terry, and Patricia Hunt. 2001. To Err (Meiotically) is Human: the Genesis of Human Aneuploidy. *Nature Reviews Genetics* 2, no. 4: 280–91.

Higher Education Today. 2018. "Meeting the Needs of Underserved Students." American Council on Education. Accessed 17 May 2020. https://www.higheredtoday.org/policy-research/meeting-needs-underserved-students/.

Hughes, Gwyneth. 2001. "Exploring the Availability of Student Scientist Identities within Curriculum Discourse: An Anti-essentialist Approach to Gender-inclusive Science." *Gender and Education* 13, no. 3: 275–90. https://doi.org/10.1080/09540250120063562.

Hutchings, Pat. 2000. *Introduction: Approaching the Scholarship of Teaching & Learning*. Edited by Pat Hutchings, *Opening lines: Approaches to the Scholarship of Teaching & Learning*. Carnegie Foundation for the Advancement of Teaching.

Hyde, Janet, Shibley, Rebecca S. Bigler, Daphna Joel, Charlotte Chucky Tate, and Sari M. van Anders. 2019. "The Future of Sex and Gender in Psychology: Five Challenges to the Gender Binary." *American Psychologist* 74, no. 2: 171–93. https://doi.org/10.1037/amp0000307.

Jester, Natalie. 2018. "Representation within Higher Education Curricula: Contextualising and Advocating for Feminist Digital Activism." *Teaching in Higher Education* 23, no. 5: 606–18. https://doi.org/10.1080/13562517.2018.1465036.

Johnson, India R., Evava S. Pietri, Felicia Fullilove, and Samantha Mowrer. 2019. "Exploring Identity-Safety Cues and Allyship Among Black Women Students in STEM Environments." *Psychology of Women Quarterly* 43, no. 2: 131–50. https://doi.org/10.1177/0361684319830926.

Kember, David, and Paul Ginns. 2012. *Evaluating Teaching & Learning*. London: Routledge.

Koppi, Tony, Judy Sheard, Fazel Naghdy, Sylvia L. Edwards, and Wayne Brookes. 2010. "Towards a Gender Inclusive Information and Communications Technology Curriculum: a Perspective from Graduates in the Workforce." *Computer Science Education* 20, no. 4: 265–82. https://doi.org/10.1080/08993408.2010.527686.

Koppi, Tony, Madeleine Roberts, and Golshah Naghdy,. 2012. "Perceptions of a Gender-inclusive Curriculum amongst Australian Information and Communications Technology Academics." *Conferences in Research and Practice in Information Technology Series* 123: 7–14.

Korolczuk, Elżbieta, and Agnieszka Graff. 2018. "Gender as 'Ebola from Brussels': The Anti-colonial Frame and the Rise of Illiberal Populism." *Signs: Journal of Women in Culture and Society* 43, no. 4: 797–21. https://doi.org/10.1086/696691.

Kuh, George, Ken O'Donnell, and Carol Geary Schneider. 2017. "HIPs at Ten." *Change: The Magazine of Higher Learning* 49, no. 5: 8–16. https://doi.org/10.1080/00091383.2017.1366805.

Ladson-Billings, Gloria. 1995. "But That's Just Good Teaching! The Case for Culturally Relevant Pedagogy." *Theory into Practice* 34, no. 3: 159–65.

Long, Sam. 2019. "Growing a Gender-Inclusive Biology Curriculum: A Framework and Reflections for Secondary Science Teachers." *The Assembly: A Journal for Public Scholarship on Education* 2: 5–10.

Luders, Eileen, Francisco J. Sánchez, Christian Gaser, Arthur W. Toga, Katherine L. Narr, Liberty S. Hamilton, and Eric Vilain. 2009. "Regional Gray Matter Variation in Male-to-Female Transsexualism." *NeuroImage*, 46, no. 4: 904–907. https://doi.org/10.1016/j.neuroimage.2009.03.048.

Mercer-Mapstone, Lucy, and Gina Mercer. 2018. "A Dialogue Between Partnership and Feminism: Deconstructing Power and Exclusion in Higher Education." *Teaching in Higher Education* 23, no. 1: 137–43. https://doi.org/10.1080/13562517.2017.1391198.

Mercer-Mapstone, Lucy, and Catherine Bovill. 2020. "Equity and Diversity in Institutional Approached to Student-Staff Partnership Schemes in Higher Education." *Studies in Higher Education* 45, no. 12: 2541–57. https://doi.org/10.1080/03075079.2019.1620721.

Miller, Abby, Katherine Valle, and Jennifer Engle. 2014 Access to Attainment: An Access Agenda for 21st Century College Students. Institute for Higher Education Policy.

Nicolazzo, Z. 2014a. "Celluloid Marginalization: Pedagogical Strategies for Increasing Students' Critical Thought Through the Multiple (Re)Readings of Trans* Subjectivities in Film." *Journal of LGBT Youth* 11, no. 1: 20–39. https://doi.org/10.1080/19361653.2014.840762.

Nicolazzo, Z. 2014b. "Couldn't I be Both Fred and Ginger?": Teaching About Nonbinary Identities Through Memoir." *Journal of LGBT Youth* 11, no. 2: 171–75. https://doi.org/10.1080/19361653.2013.878860.

Parker, Lesley H., and Léonie J. Rennie. 2002. "Teachers' Implementation of Gender-Inclusive Instructional Strategies in Single-Sex and Mixed-Sex Science Classrooms." *International Journal of Science Education* 24, no. 9: 881–97. https://doi.org/10.1080/09500690110078860.

Passarge, Eberhard. 2017."*Color Atlas of Genetics*." Stuttgart: Thieme Medical Publishers. https://doi.org/10.1136/jmg.33.9.807-b.

Rametti, Giuseppina, Beatriz Carrillo, Esther Gómez-Gil, Carme Junque, Santiago Segovia, Angel Gomez, and Antonio Guillamon. 2011. "White Matter Microstructure in Female to Male Transsexuals before Dross-Sex Hormonal Treatment. A Diffusion Tensor Imaging Study." *Journal of Psychiatric Research* 45, no. 2: 199–204. https://doi.org/10.1016/j.jpsychires.2010.05.006.

Rendon, Laura I., and Richard O. Hope. 1996. *Educating a New Majority: Transforming America's Educational System for Diversity*. San Francisco: Jossey-Bass.

R Core Team. 2019. *R: A Language and Environment for Statistical Computing* (Version 3.6.1) [Computer software]. R Foundation for Statistical Computing.

RStudio Team. 2015. *RStudio: Integrated Development for R* (Version 1.2.5001) [Computer software]. RStudio, Inc.

Seidman, Alan. 2012. College Student Retention: Formula for Student Success. New York: American Council on Education.

Seymour, Elaine, and Nancy Hewitt. 2000. *Talking About Leaving: Why Undergraduates Leave the Sciences*: Westview Press.

Schultz, Madeleine. 2014. "Teaching and Assessing Ethics and Social Responsibility in Undergraduate Science: A Position Paper." *Journal of Learning Design,* 7, no. 2: 136–47.

Smith, Jessi L., Ian M. Handley, Alexander V. Zale, Sara Rushing, and Martha A. Potvin. 2015. "Now Hiring! Empirically Testing a Three-Step Intervention to Increase Faculty Gender Diversity in STEM." *BioScience* 65, no. 11: 1084–87. https://doi.org/10.1093/biosci/biv138.

Smith, Michelle K., and William B. Wood. 2016. "Teaching Genetics: Past, Present and Future" *Genetics* 2016, no. 1: 5–10.
https://doi.org/10.1534/genetics.116.187138.

Snapp, Shannon D., Hilary Burdge, Adela C. Licona, Raymond L. Moody, and Stephen T. Russell. 2015. "Students' Perspectives on LGBTQ-Inclusive Curriculum." *Equity and Excellence in Education* 48, no. 2: 249–65. https://doi.org.10.1080/10665684.2015.1025614.

Strayhorn, Terrell L. 2012. *College Students' Sense of Belonging: A Key to Educational Success for All Students*. Oxfordshire, UK: Routledge.

Theobald, Elli J., Mariah J. Hill, Elisa Tran, Sweta Agrawal, E. Nicole Arroyo, Shawn Behling, Nyasha Chambwe, Dianne Laboy Cintrón, Jacob D. Cooper, Gideon Dunster, Jared A. Grummer, Kelly Hennessey, Jennifer Hsiao, Nicole Iranon, Leonard Jones, Hannah Jordt, Marlowe Keller, Melissa E. Lacey, Caitlin E. Littlefield, Alexander Lowe, Shannon Newman, Vera Okolo, Savannah Olroyd, Brandon R. Peecook, Sarah B. Pickett, David L. Slager, Itzue W. Caviedes-Solis, Kathryn E. Stanchak, Vasudha Sundaravardan, Camila Valdebenito, Claire R. Williams, Kaitlin Zinsli, and Scott Freeman. 2020. "Active Learning Narrows Achievement Gaps for Underrepresented Students in Undergraduate Science, Technology, Engineering, and Math." *Proceedings of the National Academy of Sciences*: 201916903. https://doi.org/10.1073/pnas.1916903117.

Varsavsky, Cristina, Kelly E. Matthews, and Yvonne Hodgson. 2013. "Perceptions of Science Graduating Students on their Learning Gains." *International Journal of Science Education* 36, no: 6: 929–51. https://doi.org/10.1080/09500693.2013.830795.

Wood, Julia T. 2013. *Gendered Lives: Communication, Gender, and Culture* (10th ed., International ed.). Wadsworth: Cengage Learning.

APPENDIX A

Useful terms for subject instructors

Transgender: An umbrella term for people whose gender and/or expression does not match the identity assigned to them at birth. Often shortened as "trans."

Nonbinary: An umbrella term for people who are not men or women. They may or may not identify as transgender as well as nonbinary.

Cisgender: Someone who is not transgender. Cisgender people identify with the gender they were assigned at birth. It is often shortened to "cis."

Intersex: A person born with any manner of supposed "ambiguity" in terms of gendered physical characteristics. This can include reproductive organs, genitals, hormones, chromosomes, or any combination thereof. Many intersex people are medically coerced as infants and children to better fit into a cisgender role. Intersex people are not inherently transgender.

Endosex: Someone who is not intersex. While genital configuration is most often used to assign gender at birth, by no means is it comprehensive, accurate, or even wholly relevant to actual variations in physiology or biology. Many people are assumed to be endosex at birth but may find out later in life that their biological sex is not what they had expected based on their birth assignment.

Sexuality or **sexual orientation**: Refers to if and to whom one is sexually attracted. Gender and sexuality are not the same thing.

Pronouns: The words by which one is referred to, whether they be "he," "she," "they," "ze," or any other. It is best to always ask someone their pronouns if possible and to not make assumptions. Always be sure to respect a person's pronouns, use them, and apologise if you slip up. Everyone has preferred pronouns, not just trans people. Anyone of any gender can use any pronouns they choose, though it's important to remember that colonialism and binarism forced the abandonment of indigenous and cultural language around gender, including pronouns that are now lost.

Transphobia: The fear or hatred of trans people or those perceived as such.

Cissexism: A form of transphobia. A system of oppression where it is assumed that one's gender identity matches their birth assignment and punishes anyone who deviates from this expectation. Cissexism also depends on a gender binary, erasing and invalidating the vast spectrum of gender expression and identity. It also includes the association of genitalia and/or body parts with gender, usually in statements like "If only men knew what it was like to have a period!" Assumptive gender attribution is a form of casual cissexism.

Misgendering: A form of transphobia. The act of attributing the wrong gender to a person, whether intentionally or not. Calling trans women "men" is misgendering. Calling someone "it" when they have asked you to use a different pronoun is misgendering. The best way to avoid misgendering people is to ask them what their gender is and what terms they prefer others to use when referring to them.

Medicalisation: The process by which human conditions and problems come to be defined and treated as medical conditions, and thus become the subject of medical study, diagnosis, prevention, or treatment. Trans peoples' bodies are often medicalised by the healthcare community.

(Sources: Trans Language Primer <https://www.translanguageprimer.org/primer>, The Anti-Oppression Network <https://theantioppressionnetwork.com/resources/terminologies-of-oppression/>)

Additional Notes:
Outdated terms to avoid:
"Hermaphrodite" is an incorrect and harmful slur towards **intersex** people.
"Transsexual" is similarly harmful. The preferred term is **transgender**.
"Sexual reassignment surgery" or "sex change" are outdated terms for **gender affirmation surgery**.

Important note on medical terminology:
Some terminology employed in scientific contexts will have unintended impacts in social situations. For example, although being intersex is medically classified as a disorder, it is harmful to call all intersex people disordered.

Although "male" and "female" are generally used to describe people with XY chromosomes who produce sperm, and people with XX chromosomes who produce eggs, it is hurtful to define trans women as male and trans men as female. There is ordinarily no need to comment on the disconnect between one's gender identity, biological sex, and chromosomes. If absolutely necessary, avoid using terms that will misgender the person. As a general rule, don't equate gender with genitalia. For example, if a trans man has not undergone gender affirmation surgery, you would simply say he still has a uterus instead of calling him female.

APPENDIX B

Sex vs. gender assessment quiz questions

1. True or false: Gender identity is defined by sex chromosomes. (1 mark)

[ANSWER, 1 mark: False. Gender identity is a social construct and has nothing to do with biology.]

2. What is the difference between biological sex and gender identity? (2 marks)

[ANSWER, 2 marks: Biological sex is influenced by chromosomes, reproductive system, hormones, and genitalia—your physical, biological attributes (1 mark). Gender identity is a social construct, defined by the ideas that have been created and accepted by people in societies (1 mark).]

3. Are all people with XX chromosomes female? (1 mark)

[ANSWER, No.]

4. What is chromosomal mosaicism? Describe one mechanism that causes this. (3 marks)

[ANSWER, 3 marks: Chromosomal mosaicism is when one organism has two or more population of cells with different genotypes/chromosomal arrangement/genetic content (1 mark). Chromosomes non-disjunction (1 mark) when homologous chromosomes or sister chromatids do not separate during cell division (1 mark), OR anaphase lag (1 mark) when sister chromosomes to not separate as not securely bound to the spindle (1 mark).]

5. Why is sex not a binary? (2 marks)

[ANSWER, 2 marks: Sex is not a binary because sex is influenced by multiple factors beyond your chromosomes (1mark). Chromosomes also do not conform to a binary as there is a prevalence of intersex people born with different chromosomal arrangements (1 mark).]

6. What are some examples of different combinations of sex chromosomes? List 3. (3 marks)

[ANSWER, 1 mark per correct combination; Possibilities: XX, XY, XXY, XXX, XYY, X, Y, XXXX XXXY, XXYY, XXXXY, XXXXX.]

7. On average, what percentage of the population are intersex? (1 mark)

a) ~0.1–0.3 percent

b) ~1–2 percent

c) ~10–20 percent

d) ~40–50 percent

[ANSWER, the answer is b) 1–2 percent]

8. A person's gender identity, gender expression, and sexual orientation can all be fluid throughout their lifetime. Can aspects of a person's biological sex also change? (1 mark)

[ANSWER, Yes. To elaborate, aspects of biological sex like hormone, genitalia, reproductive systems can change either by medical intervention (genitals, reproductive systems) or by physical fluctuations over time such as hormonal fluctuations.]

Total marks /14