Vol 13 | Issue 1 (2025) | pp. 130-148

JOURNAL OF
Perspectives in Applied Academic Practice

https://jpaap.ac.uk/

Creativity embedded in the biology curriculum

Heather A McQueen, Fizzy Abou Jawad, Alison Cullinane, Elise Darmon

School of Biological Sciences, University of Edinburgh

ABSTRACT

This article describes an intervention that was implemented in a School of Biological Sciences to improve students' attitudes and experiences of creativity in learning. Initial surveys showed that our students did not feel that there were sufficient opportunities for creativity within their curriculum and that many students did not recognise their own creative potential. Given the importance of creativity to student learning, and to their futures, we designed a series of activities to encourage student creativity and embedded the activities within the first semester of our core biology first-year curriculum. Activities were designed to develop four overlapping aspects of student learning, to: i) value creativity, ii) appreciate the connection between creativity and learning biology, iii) build students' self-belief in their own creative potential, and iv) develop their creative skills. We share our reflections as staff members delivering this intervention in two course iterations. We then present examples of student outputs, feedback comments, and personal reflections from students' reflective portfolios. Finally, we discuss key lessons learned and offer closing thoughts on the integration of creativity into our biology curriculum.

Keywords: uncertainty, skills development, science education, reflective practice, student agency

Introduction and background

Creativity is an essential skill for biologists and for any activity requiring problem-solving, research or effective learning. Definitions for creativity vary but the two core elements are originality and effectiveness (Lemmetty et al., 2021). There is a long-standing tendency to define creativity as a personal quality belonging to only a subset of individuals. Some people display marked creative skills in specific areas, such as drawing or making music. However, we now recognise creativity as a common everyday practice and we know that creative skills can be learned and improved (Baer, 2013; Martin et al., 2007; McWilliam & Dawson, 2008). Creativity is now understood to be highly collaborative in nature, and even individual creative acts are recognised to be strongly socially influenced (Lemmetty, et al., 2021). To incorporate diverse notions of creativity, in this article we define creativity as the skill of producing novel and relevant ideas or solutions to problems.

Creativity is considered a 21st century skill because of its critical importance for student success, and its anticipated importance to their futures (Biskjaer et al., 2021). Creativity is perhaps the skill most valued by employers, 70% of whom currently consider it the skill most expected to rise in importance (McWilliam & Dawson, 2008; Statista, 2024). Students must learn to be creative in many ways if research horizons are to be expanded to meet the future needs across disciplines (OECD, 2018). Universities have a particular responsibility to embed creative skills in their curriculum, not least because of the increasing value of creativity in this age of expanding artificial intelligence where true human creativity has not yet been

reproduced by generative AI (Kirkpatrick, 2023; Rampersad, 2020). The skill of creativity is therefore undeniably an important and desirable graduate attribute (McWilliam & Dawson, 2008).

Creativity is also inextricably intertwined with learning, making it an important skill to practise both during and after university. Meaningful learning requires something new to become understood and effectively integrated into previously understood concepts (Ausubel, 1963), making creativity (novelty and effectiveness) a pre-requisite for learning (Lemmetty, et al., 2021). In addition, everyday creativity has also been linked with improved wellbeing and life satisfaction (Ranjan & Gabora, 2013) which, together with meaningful learning, are critically important issues for students. It is, therefore, essential that students are supported to identify and develop their creative skills both to help their current learning and for their future employment (OECD, 2018).

In the field of biological science, creativity is of significant value for problem solving, critical thinking and innovation, yet it is rarely explicitly taught in biological science courses. Adams et al. (2009) surveyed 25 UK bioscience HE institutions and found only four provided training in creative skills. Even in these institutions, creativity was not a core activity for all students (Adams et al., 2009). To support the inclusion of creativity in our university curriculum, we aimed to design a series of activities that would be embedded across a compulsory first-year first-semester biology course. Before designing our course interventions, we first carried out a series of surveys and trials to better understand student attitudes towards creativity to allow us to best serve their needs.

Pre-intervention attitudes to creativity in the biology curriculum

Survey data were collected prior to introduction of the resources into the curriculum. Staff and undergraduate students were asked, via paper surveys (Appendix 1), for their definitions of creativity and a thematic analysis was conducted on the answers (Table 1). The responses demonstrated varied interpretations of creativity and were used to establish our definition above. Students in years 1-4 of their undergraduate biological science degree at this university were also surveyed during lectures using QR codes linked to Microsoft forms (Appendix 2). Students from each year of study rated the importance of creativity in the curriculum as greater than 7/10 (Table 2). Despite this affirmed importance, we also found that undergraduate students across all years agreed that there was a shortage of creative opportunities during their study (rated between 4.5 and 5.5 out of 10). Most worryingly, there was no obvious progression in self-rated creativity throughout the biology degree, with second and third-year students rating their own creativity marginally lower than first year students (Table 2). This suggests that our curriculum was not recognised to develop our students' creativity. Strikingly, our survey showed that less than half of our students believed that creativity could be learned (Figure 1). Further data collected at workshops showed that 15 of 31 students felt that they were not receiving adequate support to develop their creativity as part of their degree and 23 of 31 students agreed that the introduction of creative activities to their courses could improve their learning experience. This data provided a clear call to address creativity more directly in our biology curriculum.

Table 1 Thematic analysis of creativity definitions given by staff and undergraduate students. The number of times each category was mentioned is indicated. Some definitions were categorised under more than one theme. Students (n=30) staff (n=33).

Categories	Student	Staff	Examples
Out-of-the-box thinking	15	8	"Being able to think out-with the obvious' & 'Ability to think outside of the box"
Creation	14	8	"Using imagination to build or make something new, without obeying rules or established procedures"
Problem solving	2	10	"Ability to find new solutions to established problems"
Unusual connections of ideas	2	6	"Capability to connect apparently unrelated areas based on a solid starting knowledge"
The arts	4	1	"Being artistic, a free spirit, being crafty"

Table 2 Biological science student attitudes to creativity before the intervention. Responses to Likert scale questions are shown as averages with standard errors of the mean in brackets. Ratings could be selected from 1 -10 (1 being lowest and 10 being highest). The number of students responding is shown in square brackets.

	Year 1 [n=114]	Year 2 [n=43]	Year 3 [n=28]	Year 4 [n=27]	All students [n=212]
How important is it to practice creativity as part of your studies?	7.2 (0.2)	7.3 (0.4)	7.3 (0.4)	7.1 (0.4)	7.2 (0.2)
How creative are you?	6.6 (0.2)	6.4 (0.4)	6 (0.4)	6.8 (0.3)	6.5 (0.1)
Within your degree so far, how much opportunity have you had to be creative?	4.6 (0.2)	4.9 (0.3)	5.5 (0.3)	4.5 (0.3)	4.8 (0.1)

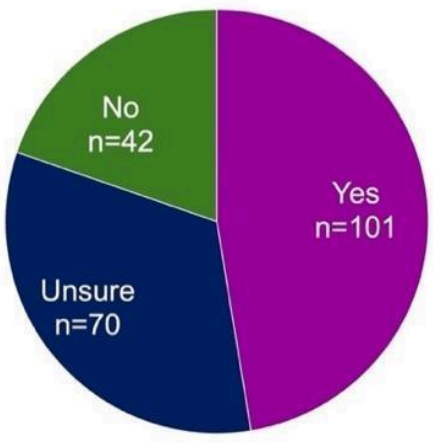


Figure 1 Student responses, before the intervention, to the question Do you think creativity can be learned?

Activities were designed to encourage, develop and reward creativity

Activities were designed with four aims in mind: i) to highlight the widespread value of creativity, ii) to highlight the connection between creativity and learning biology, iii) to encourage self-belief and confidence in individual student's own creative abilities or potential, and iv) to allow practice to build confidence with further developing this skill.

We first piloted two activities as an optional extra for first-year students. One was a group idea-generation activity and the other was Sciku writing (scientific Haikus) (Holmes, 2017). Both activities were carried out in groups of between four and six students. The idea generation activity was based on the fridge magnet activity by Adams et al., (2010), but with guidance from the STAR legacy (Martin et al., 2007). It involved first thinking individually about a real-world problem (how to spread information about vaccines amidst the rise of the anti-vaccination movement and writing one idea to address the problem onto a card. The card was pushed face down into the centre of the table before repeating with as many suggestions as possible within two minutes. Because creativity involves novelty, it is necessary to move past the obvious ideas to reach the most creative ones, but fear of peer criticism can inhibit these less obvious or more unusual ideas. The silent use of face down cards encourages more creative suggestions and avoids dominators within the group (Adams et al., 2009). After idea generation, the group discussed each idea in turn and selected the most creative two for sharing with the other students. For Sciku writing, students were asked to work together to generate a haiku about course content as a revision exercise. Together, these activities encouraged students to discover their own creativity, highlighted the relevance of creativity for learning and allowed students to practise creativity and to build confidence in their own abilities. In small group trials, both activities were found to be successful and well received by volunteer first-year students (Abou Jawad, 2020).

We then designed a suite of activities (described in Table 3) to address the four aims outlined above. During the design of activities, we carefully adhered to the guidelines given by Gregerson et al. (2013) to build clarity, encourage student agency and provide support throughout. It was also important to us that our students would derive enjoyment from these activities as a route to community building. We, therefore, used a co-creation process working with undergraduate students as partners to design and refine the activities so that the activities would be valuable and enjoyable for students (Abou Jawad, 2020; Abou Jawad et al., 2021; Dollinger & Lodge, 2019). To build confidence, we designed activities for each week of term with the purpose of the activities included in weekly lesson learning objectives. Many of the activities were intentionally loosely structured such that the students could choose their own approach and often the topic that they would explore. None of the activities had prescribed recipe-like structures or single correct conclusions, providing space and agency for the students to develop their own positive creative identities (Lemmetty et al., 2021). Most of the creative activities were not linked to assessments, to allow risk-taking whilst nurturing intrinsic motivation rather than score-seeking motives (Baer, 2013; Ranjan & Gabora, 2013). Throughout the semester our students were required to complete a reflective portfolio (described later) facilitating the individual reflection required for attitudinal change.

The creative activities were embedded within timetabled workshops in our compulsory biology course where they were distributed throughout the first semester (Figure 2). The activities were carried out in groups of between four and six students to maximise the benefits of interactions for creativity (Adams et al., 2010). McWilliam and Dawson (2008) describe creativity as the product of multiple human interactions in complex environments, but Biskjaer et al. (2021) warns of the need for group members to spend time together, to be familiar with one another and to have psychological safety to create an appropriate

breeding ground for creative thinking. We, therefore, took a careful approach to establishment and support of groupwork where sensitivity to the needs of others was regularly addressed by workshop activities (McQueen, 2024). Briefly, groups were fixed throughout the semester and met weekly in a face-to-face timetabled setting where they were supported to attend to the process of group working with a focus on cooperativity as opposed to competition (Johnson et al., 1998; Tanner et al., 2003).

There were three group assessment tasks requiring significant student creativity (Table 3) for which the students had considerable freedom of choice. The tasks incorporated peer review and feedback and were low stakes (formative or worth 5% of course points) encouraging both group and individual accountability which was achieved by adjusting marks according to peer ratings. Freedom of choice was greatest in our creative task where the groups were tasked to "plan, construct, rehearse and present a short creative and engaging piece that is relevant to biology and that addresses at least 1 of the UN sustainable development goals" (United Nations, 2015). The only other requirement was that the work would be presented within five minutes and would take up no more than 2m3 of space. To help with any confusion arising from this freedom, class activities and support were provided to help establish shared ideas and group goals. Due to student choice, the group submissions for assessments were all different and we used a wire-framed assessment design whereby the assessment criteria were clear but how to reach them was determined by the students (Baer, 2013). For example, the assessment criteria for the creative task reflected i) relevance to biology, ii) inclusion of at least one sustainable development goal, iii) engaging the audience, and iv) being creative. The outputs from our creative task were presented and marked by classmates and staff during a timetabled creative event which was designed to generate engagement, motivation and satisfaction through enjoyment (Snyder, 2013).

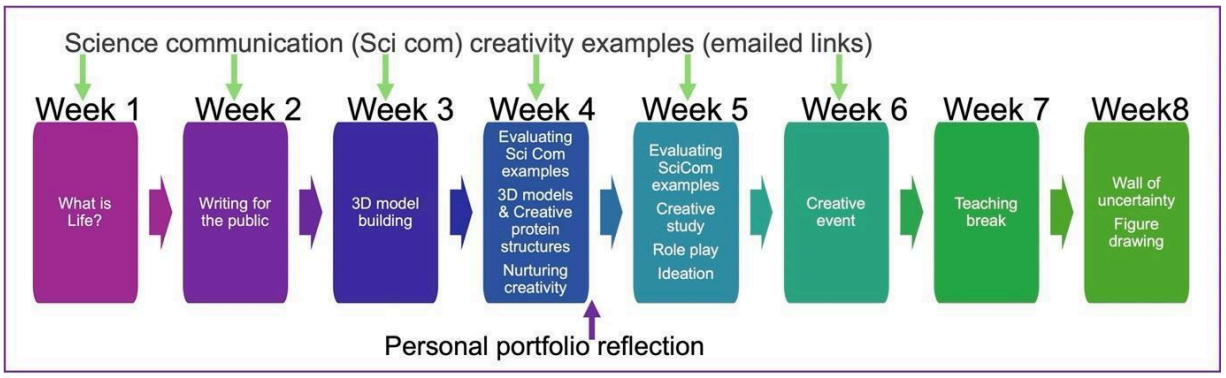


Figure 2 A map of creative interventions across one compulsory first-semester first-year biology course. Coloured boxes represent weekly workshops where students worked within the same group each week. Only weeks 1-8 are shown, as week 9 workshop was used for a mock test, and weeks 10 and 11 were free for students' own choice of collaborative work. There were no class activities during week 7. All activities are described in Table 3.

Table 3 Creative activity descriptions and purposes (G = group, I = individual). The purposes of the activities were i) to value creativity, ii) to appreciate the connection between creativity and learning biology, iii) to build self-belief in each student's own creative potential, and iv) to develop their own creative skills. Some activities were also for introducing and accepting uncertainty.

Activity		Description of activity	Purpose of Activity
What is life? (formative assessment)	G	Discussion of a highly complex problem, without access to the internet, to generate questions and keywords.	iii) self-belief, iv)develop skill and accepting uncertainty
Science communication creativity examples	I	Links to online examples of creative science communication outputs supplied as a drip-feed over six weeks of course organiser emails.	i) Value, ii) connection
Evaluating science communication creativity	G	Group discussion and marking from a choice of 20 examples of creative science communication (same marking criteria as own creative task).	i) Value, ii) connection and understanding evaluation criteria
3D model building	G	Using 3D printed and atomic models to build DNA and protein structures.	ii) connection, iv) develop skill
Creative protein structure	G	Explicitly highlighting creativity required for development of tools (such as PyMol) for understanding protein folding.	ii) connection
Writing for the public (assessment)	G	Addressing own group question from 'What is life?' in a style accessible to the public. Low-stake group assessment.	iii) self-belief, iv) develop skill
Nurturing creativity discussion (pot of questions)	G	Student-chaired discussion of questions 1) Are scientific accuracy and creativity contradictory? 2) Is creativity a relevant skill for being a biologist? 3) Can creativity be learned?	ii) connection, iii) self-belief
Portfolio reflection on creativity	I	Students privately reflect upon their own creativity or the relevance of creativity to science within their reflective portfolio.	ii) connection, iii) self-belief
Creative study	G	Group generative note taking (drawing a mind-map) on lecture material.	i) Value, ii) connection, iv) develop skill
Koala role play	G	Prompted interactive role play game to discuss an ethical environmental issue affecting koala bears.	i) Value, ii) connection, iv) develop skill
Ideation	G	Creative solution ideation technique applied to chosen sustainable development goals.	i) Value, ii) connection, iv) develop skill
Wall of uncertainty	G	Posting ideas on a communal wall- things that science may be wrong about.	ii) connection, iv) develop skill and accepting uncertainty
Drawing figure	G	Collaborative drawing and peer-evaluating of own figure to accompany assessed work.	ii) connection, iv) develop skill
Creative task and event (assessment)	G	Producing and evaluating creative group work for creative events. Free choice of topic and media. Performed at enjoyable social event. Marked by staff and students (equal weight).	i) Value, ii) connection, iii) self-belief, iv) develop skill

Staff experiences of creativity interventions

As instructors, we (authors HMcQ, AC & ED) found that embedding creativity into our biology curriculum enlivened our course activities and made the learning sessions more enjoyable to teach. The 'What is life?' discussion activity during our week one workshop (which for some students was on day one of university) was a pivotal moment which seemed to animate our students, who visibly engaged, taking control of their own learning. Although the day of our very first creative event (in week six) was a uniquely nervous

occasion for us, we now consider this to be the highlight of the course and have been consistently impressed during the first three iterations by the standard of students' creative presentations. We have also been surprised by the exciting and creative array of media through which students have chosen to present their work (Table 4). The creative media choices did not only impress us the first year as, even at our third iteration of the event, students still found novel ways to present their creative task. The most common presentation type was cooking or baking (Figure 3a), commonly with cakes available to share such as the highly memorable maggot cake, baked while investigating novel food sources to feed the expanding population (Figure 3b). The groups that moved farthest from normal classroom activities (such as songs, plays, the rap and the fashion show) or that gave highly interactive or humorous presentations (Figure 3c) were most highly rated by both staff and students whose marks contributed equally to the final mark.

Figure 3 Student creativity a) Cakes representing bacteria and virus particles baked by students to explain infective processes, b) cake made with insect protein (and maggot topping) by students investigating alternative food sources, c) scene from a video created by students to explore the effects of plastic pollution ingested by sea creatures, d) DNA helix assembled by students from 3D-printed components.

From the perspective of a student adviser (author FAJ), the addition of these creative activities and the preparatory work undertaken by the students had a tangible impact on the student experience. Many students created meaningful relationships with the other students in their group when creating outputs for the creative events. These relationships and the positive impact they had on individual students was visible to support staff. Students shared with support staff how their experiences, including spending time together outside of their classes, helped them to feel more comfortable and able to engage with their course. Additionally, providing students with agency at an early stage of their studies, and creating an environment where students feel comfortable with uncertainty, sets a crucial foundation that will enable

the students to thrive when embarking on their final year projects – where agency and uncertainty are core components. Many students seek support when struggling to adapt to these challenging aspects of learning during their penultimate and final years. Embedding opportunities for students to have these experiences earlier in their studies allows them to either seek support early or to begin building a repertoire of tools for use in later years when the stakes are much higher.

Table 4 Media chosen by students for creative task presentations across three course iterations. (Some presentations fell into more than one category).

Presentation media	2022	2023	2024
cake/ cooking	11	18	11
poster	3	1	1
Powerpoint presentation	1	1	
model	3	3	2
animation	2	2	2
video	4	5	14
comic/ story book	4	4	6
sculpture	2	1	4
song	1	2	6
artwork	1	1	3
picture album/ photos	1	1	1
tattoo	3		
board game	4		
Minecraft	1		
fashion show	1		
rap		1	
quiz		3	
puppet show		1	
Pinterest board		1	
play		2	
pinata		1	
origami		1	
puzzle		1	
crochet			2
storytelling			1
news report/mockumentary			2
poem			1

Student attitudes to creativity interventions

Student benefits from our creativity strategy are difficult to quantify since the intended learning and attitudinal benefits, such as valuing creativity or building self-belief, would be personal and could be expected to develop gradually and differently between individual students. Student attitudes to the interventions can be drawn from the end-of-course evaluation where students were asked to indicate and comment on their favourite workshops. All workshops were chosen by at least one student. Nineteen of the 61 students that completed the survey (31%) chose one or both molecular modelling workshops, often because of their clear links to course lecture content but sometimes recognising the playful aspect of model building, the word "fun" appearing in five comments. A DNA model assembled by one group is shown in Figure 3d. Sixteen students (26%) said that the creative event was their favourite workshop. The words "fun", "enjoyed" or "enjoyable" featured in 11 of the explanations for choosing this while seven explanations praised the socialising that the event encouraged. Other comments showed a deeper appreciation of the creativity involved such as: "it was very unique", "I was able to use my imagination", and "it was a fun way of assessing skills in a less typical manner".

A few students felt that the freedom of choice led to presentations that were not closely enough related to the course topics to be useful learning, with comments such as:

> The creative task was useful in terms of creating a more relaxed and sociable environment. It made the course more fun but it didn't necessarily add to my scientific knowledge. It felt more focused on the presentation and the entertainment aspect rather than the content.

Students enrolled on this course undertook a reflective portfolio designed to nurture academic, personal and professional development. This reflective portfolio sat across all four compulsory first year biology courses and accounted for 25% of the course assessment for each course. The reflective portfolio required students to write weekly reflections on their learning progress and skills acquisition (Cullinane, 2024). This ongoing reflection helped students to adapt to and make sense of the many non-traditional aspects of these courses, including creativity. The portfolio also directly asked students to reflect on creativity during week four, while students were planning their creative task. Students were asked to reflect on the following four prompts:

1. Describe a situation where you have had to be creative either recently or previously.
2. How did you feel when doing creative activities and tasks?
3. Evaluate how important creativity is to your life or learning and career.
4. What area in the future will require you to be creative and how will you use creativity to your advantage?

In response, students described course-related and non-course-based experiences of creativity, frequently highlighting the benefits of working together on the course tasks (see Table 5 for themes arising). Interestingly, students typically categorised themselves within their comments as either not creative and therefore challenged, or very creative and excited at the start of the task. Almost all went on to express satisfaction or a sense of accomplishment on completing creative tasks irrespective of how they had originally self-classified. In response to prompt three, students overwhelmingly recognised the importance of creativity. Only two of 307 students (0.7%) did not support the importance of creativity, one of whom used mindmaps but did not consider this generative form of note-taking as creative. The nature of the

importance of creativity that students described was very varied ranging from creativity as an escape from science which many students still considered to be fact-based, to those who recognised the essential nature of creativity to their learning and/or to science.

It is important to note that the reflective portfolios were for students' own reflection and students were encouraged to be honest and introspective, which differs from the purpose of the end-of-course evaluation which sends feedback to the instructors. This difference in intended audience and purpose is reflected in the tone of comments provided which, perhaps, makes the reflective portfolio comments more authentic.

Creativity was one of many skills addressed across our four new compulsory biology courses. At the end of the first semester students were asked, in their reflective portfolio, to select the skills they had most developed from a list of 37 skills linked to academic, personal and professional development. Students could select as many skills as they felt they had developed and 114 of 334 students (34%) selected creativity. During their second semester, students were asked to write a reflection on skills that they had engaged with to date, rating their mastery on a scale of 1-4 (where 1=emerging, and 4=mastery). Of the 83 students that elected to reflect on their creativity skills, 83% rated their mastery as 3 (proficient) or 4 (mastery) (Figure 4). One student commented:

> When previously faced with creative tasks, I have always taken them for granted and I never fully dedicated myself to them. Yet, as we encountered the creative task in the [name of course discussed here], I discovered a hidden potential within me. Surprisingly, I found myself enjoying the process immensely. Me and my group mates realised a piñata resembling the world, as it symbolised the fact that the resources of the world are being badly partitioned and used. The amount of fun I had while painting is indescribable: I realised that in biological sciences being creative is utterly important as it enables you to always get to the bottom of things and pay attention to details that others might not see. I reckon that creativity drives research further, as if we didn't have creative minds like those of the great scientist, we wouldn't have discovered many of the things we know today.

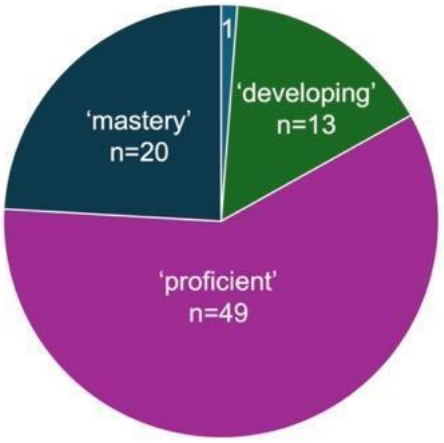


Figure 4 Student self-rated creativity mastery levels. The number of students rating their mastery level during semester 2 of first year is shown. Mastery levels were 'emerging' (light blue, only chosen by one student, description omitted) 'developing' (green), 'proficient' (purple) or 'mastery' (dark blue).

Table 5 Student-articulated benefits of creativity activities with corresponding portfolio reflection quotes.

Collaborative process furthers creativity	"During this week's 'Life' workshop, we were instructed on how to make the most out of the creative task that is due for Week 6. At first, me and my group mates were struggling to find an idea that could be appealing to the public, but as soon as we started suggesting different creative methods that could make a science notion entertaining, our minds began working synchronously and everyone added something to the previous idea that could make it even better. I reckon that expressing my opinions without feeling judged enables me to unleash my creativity even easier, as I have found people that do not limit me but instead push me to do my best."
Realising wider importance of creativity to science	"I consider creativity to be art or crafts. I feel I am not a very creative person but I think it's an important skill, both outside learning and in learning. Creativity in science is needed to come up with hypotheses and ideas on how to test them. I hadn't really considered creativity in science until now and realise I may be creative in different ways."
Development of own creativity on course	"I really worried about how to figure it out at the beginning. I had no idea how to draw creative things and how to turn several words into a picture. But as time passed, I kind of found a way to do that. I started to enjoy that. It became entertainment for me, enjoying every stroke was a fantastic thing. In the end, I finished drawing with confidence and shared that with my group."
Creativity bringing joy to learning	"I feel very excited! Because we have truly achieved innovation. Innovation in Content: We incorporated spirulina, a concept we had never explored before, to align with SDGs and share our insights. Other teams are just using concepts we've already learned. Innovative! We genuinely used and thought about SDGs, not just mentioning them casually. Innovation in Form: We created a video, the most suitable medium for communication. However, in the video, we combined reality and tradition, using real puppets to create stop-motion animation characters. We wrote a script and combined human voices with AI for voiceovers in the video. Honestly, it's pretty cool! I love it! Even if it means we did a lot behind the scenes for the video. I believe all members of our team are very satisfied with our work"
Realising that creativity can be learned	"In the life workshop this week, my group discussed whether creativity can be learned, coming to the consensus that it can be learnt. I think that the more you use your imagination, the easier it becomes to think creatively and come up with original thoughts, perspectives and ideas."
Building confidence with creativity	"I recently had to be creative because in my Life Workshop, the task due in week 6 is a creative task, and while I am not necessarily a creative person, I realised that I had to make a conscious effort to help out my group in this regard. My group accepted that, while this is not something that I am necessarily talented at, it was something that I wanted to work on, so they helped and supported me while I brainstormed ideas. I wanted to improve on my creativity, and thus I did it in this way."
Benefit of loosely defined tasks (uncertainty)	"I really enjoy doing creative tasks. I was excited at the prospect of having a writing task to do, as this is something that I like to do outside of my course. I think that not everyone enjoys creative tasks, and this comes as a part of life in general – everyone has their strengths, and a preferred way of working. During the situation, I was initially a little confused at what was being asked of us with this task, but I found that the ambiguity of the assignment allowed for a more creative product."
Benefit of wire-framed assessment criteria	"Before being creative I felt like it was impossible as I prefer following instructions and always being told what to do, but I actually enjoyed the freedom of there being no right or wrong way to complete the task."

Lessons learned and insights from embedding creativity in the biology curriculum

Overall, embedding creativity across our compulsory first year biology course has been enjoyable for staff and students, and positive for student learning. Collected evidence supports that we have achieved our aims of encouraging students to value and appreciate creativity, to build self-belief in their own creative abilities and to develop their own creative skills. We believe that these activities have had a positive, if gradual, effect on growing the creative mindset of our student population.

Some of the potential challenges of introducing creative activities, such as finding the time and resources, were avoided in our case because the interventions were integrated into plans for our new curriculum from the outset. Although student engagement was high because the activities were embedded as core content, one challenge that we did experience was low quality engagement by some students who, after minimal engagement, skipped forward to activities that they considered more worthwhile. These students doubted the value of spending contact time on creative activities. We believe this to be a result of their expectations for 'traditional' learning at university. Many first-year students are still struggling to adjust to university learning and rely on prior habits of didactic and rote learning which stifle creativity and do not encourage skills development (Martin et al., 2007). To help our students to understand the value of their creative activities, we introduced both written and verbal introductions for each workshop, explicitly highlighting the skills that students would develop each week with advice on how to use this information within their assessed reflective portfolio. Within their portfolios, students frequently expressed initial doubt about creative tasks followed by adjustment and recognition of the benefits, with many students later feeling that they had achieved proficiency or even mastery of creative skills.

Uncertainty is a necessary condition for creative learning due to the requirement for novelty (Beghetto, 2021). This presented a second challenge for us because too much uncertainty can be daunting, leading to feelings of confusion, helplessness or a disincentive to engage. It is, therefore, important to strike a balance between a sense of uncertainty, and a sense of possibility to achieve, leading to more positive wellbeing for learners (Lemmetty et al., 2021). We tried to manage this balance using planned uncertainty (Baer, 2013). For our 'What is Life?' formative assessment, at the end of the first workshop, the uncertainty was planned and explicitly acknowledged in that there was no specific correct answer. Having first taken the time to establish safe and effective groups with shared interests and agreed working rules enabled us to balance the uncertainty with support and to help students adjust. Later in the course, during the 'wall of uncertainty' activity, the student groups were encouraged to recognise the uncertain nature of scientific knowledge. Being able to manage uncertainty encourages individuals to accept intellectual risks and embrace ambiguity, which also encourages further creativity (Snyder, 2013).

A third concern was that the freedom associated with our creative task could potentially be too daunting for students within their first semester of learning molecular biology at university level. Students whose primary interests lie in other areas of biology, for example botany or ecology, often struggle with the molecular aspects of biology covered by this compulsory course. We reasoned that discomfort with the topic might restrict creativity. Additionally, the creative event happened after only five weeks of university study when many students were still adapting to new ways of learning. Our marking criteria, therefore, awarded credit for relevance to biology in general, rather than the course-restricted molecular aspect. After two iterations of the course, we also reduced the length of presentations from 5 minutes to 3 minutes to reduce the size of the task. A few students criticised the lack of improvement in relevant scientific knowledge. Although this was not the purpose of the activity, we did consider whether tasks of this nature should be restricted to course material to focus learning or whether we were right to link to the discipline

more broadly for students who were less invested in this specific course. On balance we consider that the social and academic benefits arising from engagement with our tasks made an important contribution to the process of transitioning into university. Course-focused tasks may be preferable to satisfy the academic orientation of students on optional elective courses, but for large compulsory courses it may be that the benefits of wider engagement and of building creative mindsets for all students make a broader focus more appropriate for non-traditional assessments. We do consider it to have been important that our creative activities maintained a connection with biology, and we recommend maintaining broad disciplinary connections within creativity innovations.

One final consideration was providing access and alternative methods of assessment to all students. The level of group work across this course could be expected to be challenging for some students with learning differences and may have discouraged some students from enrolling on the course. However, the high level of group work support and attention to group processing did appear to allow many students with adjustment schedules to work well within their groups, and we experienced very few group dynamic problems. The open nature of the creative task allowed students to use their specific talents and to choose to communicate their ideas in a variety of verbal, visual, and auditory ways. Students were not required to present in person and many presentations were pre-recorded. We did not investigate the specific experiences of students with disabilities or learning differences and this could be a fruitful avenue for future research.

In future studies we would also like to better understand how our students' attitudes to creativity evolved during and after these activities, and in particular how this compared to previous students who did not experience these creative activities.

When students choose to trust our institutions with their growth as a learner, we believe that we should aim to ensure that they graduate as well-rounded individuals. We have found that embedding creativity into our curriculum provided a conduit for the introduction of wider transferable skills that will be valuable to our students now and in the future. The personal reflections made by students in their reflective portfolios demonstrate increasing comfort with uncertainty, valuing agency and recognising the value of skills that they may not previously have considered important, such as creativity. Opportunities for students to flex their problem-solving and team-working abilities were interwoven across the activities, allowing formation of a strong foundation for the rest of their learning journey. Creative skills will be essential in all our biology students' future careers, including those in non-scientific employment, for finding solutions to challenges, for achieving research breakthroughs and for solving problems not yet in existence. High levels of creativity in scientific thinking will be required to open new areas of thought as seen throughout history in Copernican astronomy, quantum physics or in discovering the structure of DNA. Future generations of scientists will have to be creative to manage issues such as climate change, artificial intelligence and global sustainability problems (Morgan & Kneebone, 2023). We feel confident that our students have not only developed positive attitudes towards creativity but have also had the opportunity to use this experience to learn more about themselves and their potential for growth, illustrating to the students that they are more than their degree. From the many benefits we have seen in our teaching, we strongly encourage other educators to actively embed creativity in their curriculum.

Ethics statement

Ethical approval (reference hmcqueen-0001) was received from the School of Biological Sciences ethics committee which adopts the UK research integrity office code of practice for research. All those providing

information were made aware of current research projects and those providing outputs signed release forms. All students were advised that they were free to withdraw their consent or outputs at any point.

Acknowledgement

The authors wish to thank Calum Paterson for devising and trialling the role play activity, Sarah-Jane Judge for providing science communication creative examples, David Barrass for 3D-printed molecular components used in molecule building workshops, and Nick Colegrave for contributions to creative learning on the parallel core biology course.

Biographies

Heather McQueen is the organiser and lead developer of the described course. Her academic interests include student-posed questions for active learning, inclusion, engagement and wellbeing in large classes. Heather is Professor of Biology Education, a Senior Fellow of the Higher Education Academy and a National Teaching Fellow. Email: h.mcqueen@ed.ac.uk

Fizzy Abou Jawad is a Student Adviser, supporting students during their university journeys to leave as confident, well-rounded graduates. Fizzy previously worked as an Edinburgh University Student Union sabbatical officer. Fizzy conducted the preliminary research and originated our first creative activities as an undergraduate student. Email: fizzy.aboujawad@ed.ac.uk

Alison Cullinane is the Portfolio Director in the School of Biological Sciences where she developed and manages the reflective portfolios described here. Her research interests include formative assessment, nature of science, and reflective practice. Email: Alison.Cullinane@ed.ac.uk

Elise Darmon is a co-designer and assistant leader of the described course. Elise's interest is in developing students' active participation and communication, as well as building student confidence and awareness of the sustainable development goals. Elise is a Lecturer in Molecular Bioscience Education and a Fellow of the Higher Education Academy. Email: Elise.Darmon@ed.ac.uk

References

Abou Jawad, F-M. (2020). *Is it important to offer students the opportunity to practice their creativity in bioscience degrees and what impact does this have on student learning experience?* [Unpublished B.Sc. thesis. University of Edinburgh].

Abou Jawad, F., Agrawal N., Colegrave, N., Darmon, E., Edwards, E., McQueen, H., Paterson, C., & Pubillones, L. (2021). *An embedded pathway for student wellbeing*. https://blogs.ed.ac.uk/learning-teaching-conference/poster-an-embedded-pathway-for-student-wellbeing/

Adams, D. J., Beniston, L. & Childs, P. (2009). Promoting creativity and innovation in biotechnology. *Trends in biotechnology, 27*(8), 445-447. https://doi.org/10.1016/j.tibtech.2009.05.001

Adams, D. J., Hugh-Jones, S. & Sutherland, E. (2010). Raising awareness of individual creative potential in bioscientists using a web-site based approach. *Bioscience Education, 15*(1), pp.1–7. https://doi.org/10.3108/beej.15.5

Ausubel, D. P. (1963). *The psychology of meaningful verbal learning*. Grune and Stratton.

Baer, J. (2013). Teaching for creativity: Domains and divergent thinking, intrinsic motivation, and evaluation. In M. B. Gregerson, J. C. Kaufman, & H. T. Snyder (Eds.), *Teaching creatively and teaching creativity* (pp. 175-185). Springer. https://doi.org/10.1007/978-1-4614-5185-3

Beghetto, R. A. (2021). Uncertainty: A necessary condition for creative learning. In S. Lemmetty, K. Collin, V. P. Glăveanu, & P. Forsman (Eds.), *Creativity and learning: Contexts, processes and support* (pp 25-44). Palgrave Macmillan. https://doi.org/10.1007/978-3-030-77066-2

Biskjaer, M. M., Iversen, O. S., & Dindler, C. (2021). Cultivating creativity in computing education: A missed opportunity? I In S. Lemmetty, K. Collin, V. P. Glăveanu, & P. Forsman (Eds.), (pp. 95-113). Palgrave Macmillan. https://doi.org/10.1007/978-3-030-77066-2

Cullinane, A. (2024), Embedding a reflective portfolio for student development in science courses: Challenges, suggestions, and solution. *Teaching Matters Blog, University of Edinburgh*. https://www.teaching-matters-blog.ed.ac.uk/embedding-a-reflective-portfolio-for-student-development-in-science-courses-challenges-suggestions-and-solutions/

Dollinger, M. & Lodge, J. (2019). Understanding value in the student experience through student–staff partnerships, *Higher Education Research & Development, 39*(5), 940–952. https://doi.org/10.1080/07294360.2019.1695751

Gregerson, M. B., Kaufman, J. C., & Snyder, H. T. (2013). Teaching creatively and teaching creativity. Springer. https://doi.org/10.1007/978-1-4614-5185-3

Holmes, A. (2017). *The Sciku project*. https://thescikuproject.com

Johnson, D. W., Johnson, R. T. & Smith, K. A. (1998). Cooperative learning returns to college What evidence is there that it works? *Change: The Magazine of Higher Learning, 30*(4), 26-35. https://doi.org/10.1080/00091389809602629

Kirkpatrick, K. (2023). Can AI demonstrate creativity? *Communications of the ACM, 66*(2), 21-23. https://doi.org/10.1145/3575665

Lemmetty, S., Glăveanu, V. P., Forsman, P., & Collin, K. (2021). Creativity and learning as sociocultural and intertwined phenomena. In S. Lemmetty, K. Collin, V. P. Glăveanu, & P. Forsman (Eds.), *Creativity and learning: Contexts, processes and support* (pp. 1-24). Palgrave Macmillan. https://doi.org/10.1007/978-3-030-77066-2

Liu, E. Z. F., Lin, C. H., Jian, P. H., & Liou, P. Y. (2012). The dynamics of motivation and learning strategy in a creativity-supporting learning environment in higher education. *Turkish Online Journal of Educational Technology, 11*(1), 172-180. https://files.eric.ed.gov/fulltext/EJ976581.pdf

Martin, T., Rivale, S., & Diller, D. (2007). Comparison of student learning in challenge based and traditional instruction in biomedical engineering. *Annals of Biomedical Engineering, 35*(8), 1312–1323. https://doi.org/10.1007/s10439-007-9297-7

McQueen, H. A. (2024). Groupwork can level out educational differences during the transition to university -but class division can confound group cohesion. *Association for National Teaching Fellows blog*. https://ntf-association.com/groupwork-can-level-out-educational-differences-during-the-transition-to-university-but-class-division-can-confound-group-cohesion/

McWilliam, E., & Dawson, S. (2008). Teaching for creativity: Towards sustainable and replicable pedagogical practice. *Higher Education, 56*(6), 633–643. https://doi.org/10.1007/s10734-008-9115-7

Morgan, R., & Kneebone, R. (2023). Why creativity in science matters & three ways to achieve it. *World Economic Forum*. https://www.weforum.org/agenda/2023/07/creativity-science-matters-ways-to-achieve-it/

OECD. (2018). *The future of education and skills Education 2030*. https://www.oecd.org/en/about/projects/future-of-education-and-skills-2030.html

Rampersad, G., (2020). Robot will take your job: Innovation for an era of artificial intelligence. *Journal of Business Research, 116*, 68-74. https://doi.org/10.1016/j.jbusres.2020.05.019

Ranjan, A., & Gabora, L. (2013). Creative ideas for actualizing student potential. In S. Lemmetty, K. Collin, V. P. Glăveanu, & P. Forsman (Eds.), *Creativity and learning: Contexts, processes and support* (pp. 119-133). Springer. https://doi.org/10.1007/978-1-4614-5185-3

Snyder, H. T. (2013). Designing creative assignments: Examples of journal assignments and a creative project. In S. Lemmetty, K. Collin, V. P. Glăveanu, & P. Forsman (Eds.), *Creativity and learning: Contexts, processes and support* (pp. 163-175). Springer. https://doi.org/10.1007/978-1-4614-5185-3

Statista (2024). *Skills expected to rise in importance from 2023 to 2027*. https://www.statista.com/statistics/1383183/skills-on-the-rise/

Tanner, K., Chatman, L. S., & Allen, D. (2003). Approaches to cell biology teaching: Cooperative learning in the science classroom—Beyond students working in groups. *Cell Biology Education, 2*(1). https://doi.org/10.1187/cbe.03-03-0010

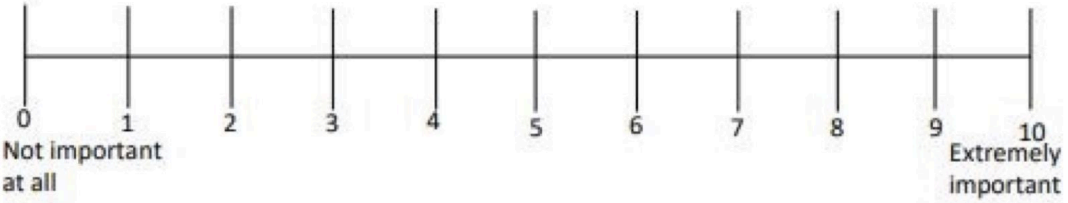
United Nations. (2015). *The 17 goals*. Department of Economic and Social Affairs, Sustainable development. https://sdgs.un.org/goals

Appendices

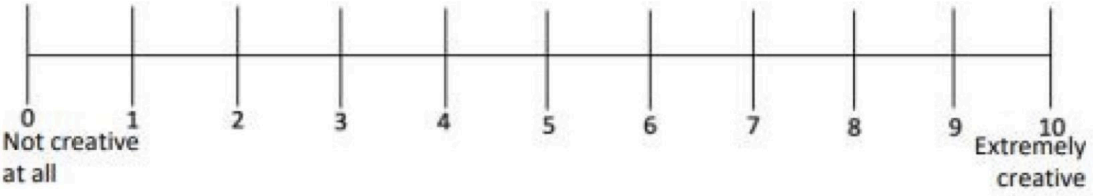
Appendix 1a: Survey given to staff to gain understanding on attitudes toward creativity, including definitions for creativity.

Staff Creativity Survey

1. How important do you think it is to have creativity in the curriculum?



2. How creative are you?



3. Do you think creativity can be learned?
(Tick one)

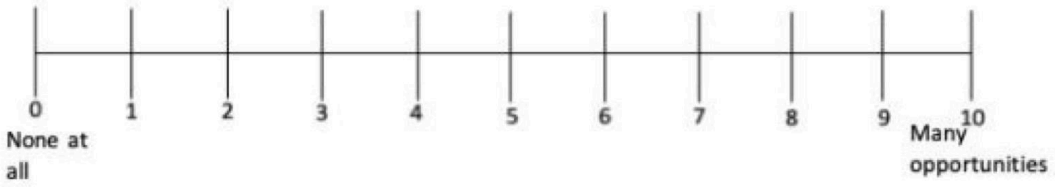
☐ Yes ☐ No ☐ Unsure

4. How would you define creativity in one sentence?

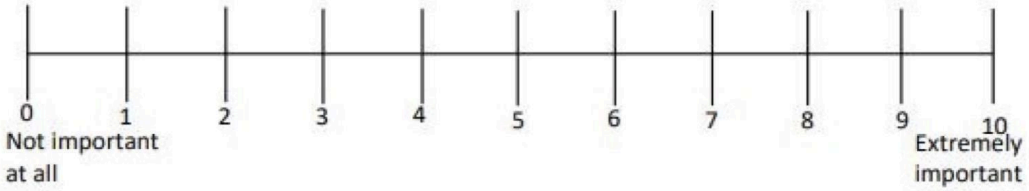
Appendix 1b: Survey given to students to gain understanding on attitudes toward creativity, including definitions for creativity.

Pre-Activity Creativity Survey

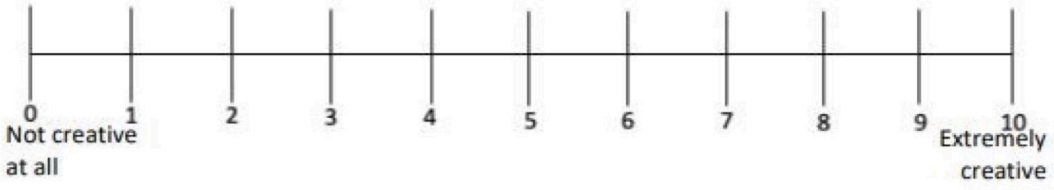
1. Within your degree so far, how much opportunity have you had to be creative?



2. How important do you think it is to practice creativity as part of your studies?



3. How creative are you?

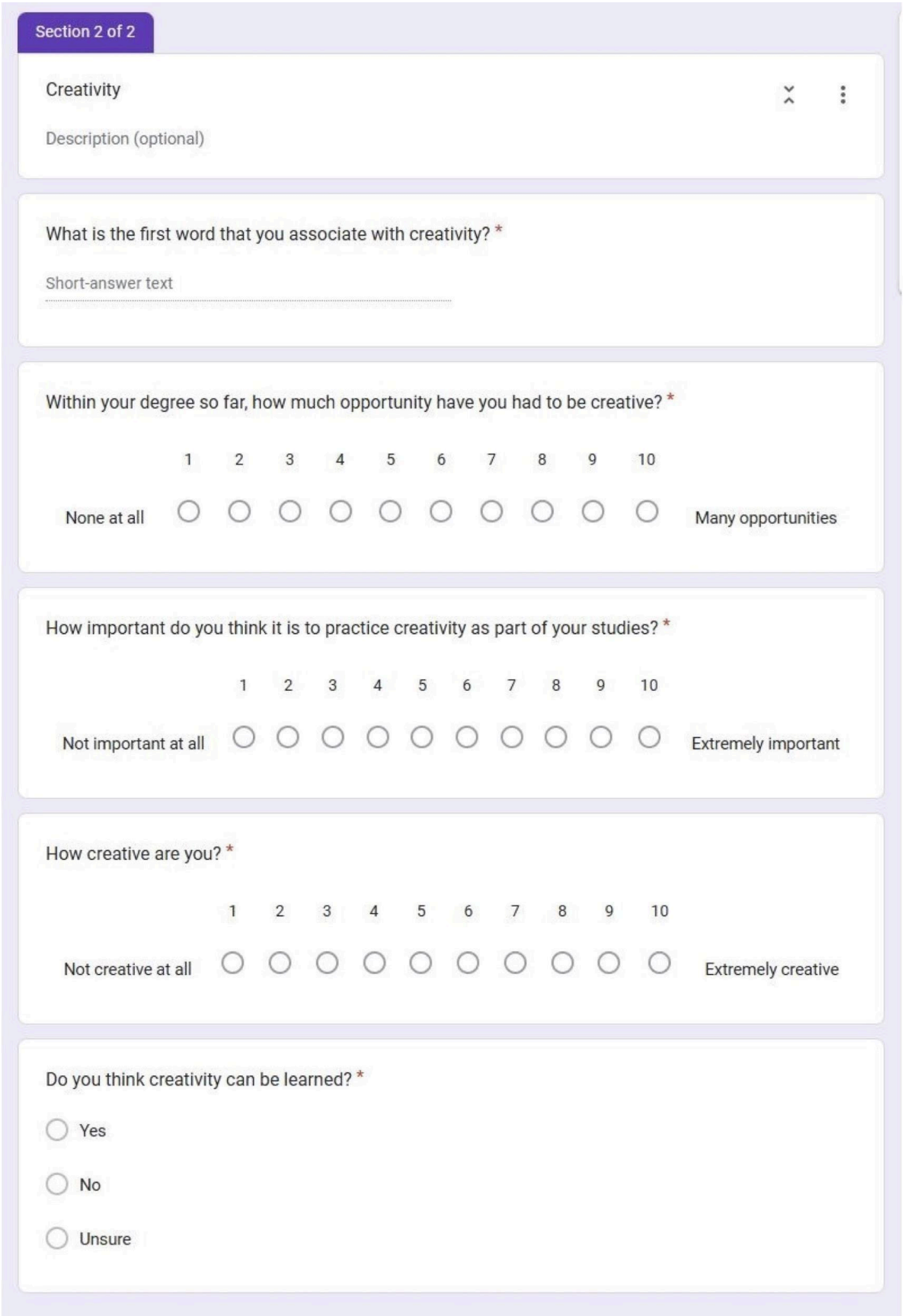


4. Do you think creativity can be learned?
(Tick one)

☐ Yes ☐ No ☐ Unsure

5. How would you define creativity in one sentence?

Appendix 2: Survey administered to students during lectures to gain understanding on experiences and attitudes toward creativity at university.



Section 2 of 2

Creativity

Description (optional)

What is the first word that you associate with creativity? *

Short-answer text

Within your degree so far, how much opportunity have you had to be creative? *

	1	2	3	4	5	6	7	8	9	10	
None at all	○	○	○	○	○	○	○	○	○	○	Many opportunities

How important do you think it is to practice creativity as part of your studies? *

	1	2	3	4	5	6	7	8	9	10	
Not important at all	○	○	○	○	○	○	○	○	○	○	Extremely important

How creative are you? *

	1	2	3	4	5	6	7	8	9	10	
Not creative at all	○	○	○	○	○	○	○	○	○	○	Extremely creative

Do you think creativity can be learned? *

- ○ Yes
- ○ No
- ○ Unsure