On Creativity and Innovation in the Computing Curriculum

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ABSTRACT

Graduates of computing degrees are extremely well placed to be entrepreneurs of the future. They have knowledge of recent advances in computing hardware, software and data sources, and skills to turn that knowledge into digital products like software applications and mobile apps that appeal to consumers or businesses. While entrepreneurship education encompasses many aspects, a starting point is finding a good idea that has market potential. This requires creativity: a skill that is not often made explicit in computing programs, or if so, perhaps confined to the realms of HCI or coding. Moreover, in many computing subjects, students are asked to find creative solutions to known problems, rather than exploring the problem space itself. This paper describes a case study of inviting students to demonstrate creativity and innovation in an e-commerce subject offered principally to computing students. Students are asked to identify human-centered problems that lend themselves to computing-oriented solutions, and to propose and test their ideas. The paper identifies four factors that were examined in relation to their influence on students' creativity and innovation.

CCS CONCEPTS

• **Social and professional topics~Computing education programs** • *Social and professional topics~Socio-technical systems* • *General and reference~Design* • Applied computing~Collaborative learning

KEYWORDS

Creativity; Innovation; Entrepreneurial outlook; E-commerce

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1 INTRODUCTION

Entrepreneurs come from varied backgrounds, but there is debate over whether they have become entrepreneurs because of the education they have received, or in spite of it. Formal education in entrepreneurship tends to belong to the domain of business or commerce faculties at universities, and indeed, this is generally the right place for teaching the skills needed to take a novel idea and turn it into a business reality.

But when and where do we encourage computing students to have novel ideas? How might we empower them to see the computing profession not merely as solving other people's problems, but a vehicle for them to generate their own new ideas and pursue these into commercial reality? How might we better foster creativity and innovation in computing students?

That is not to say that creativity is not already included and valued in computing curricula, or even that the notion of creativity in computing curricula is a new idea. For example, in 2003, Sweeney examined the value and positioning of creativity in the IS and IT model curricula [10]. The problem is that in many approaches, including Sweeney's, creativity is considered as simply a tool for problem solving. Moreover, it is often seen as a tool for students to find creative solutions to *known problems*, rather than applying creativity to find *new problems* to solve.

Creative problem solving is a necessary, but not sufficient, capability for computing graduates of the future.

Creativity also commonly appears in computing curricula when designing how humans interact with computers. For example, game design [5] or human-computer interaction [3] subjects often encourage creativity in students. Again, it is important for students pursuing careers in these fields to be equipped with creative thinking, but there is still a broader application of creativity that deserves greater consideration.

This paper presents a working definition of creativity and innovation that is relevant for computing curricula and that allows our students to see themselves as creators of the future. We explore the notion of creativity as a tool for idea generation, not merely creative problem solving. We examine this through a case study of a subject on e-commerce, where students were

asked to develop ideas for new electronic products or services by following a human-centered design approach.

2 CONTEXT

2.1 Creativity

Before continuing, we should define how the terms creativity and innovation will be used in this paper, as there are many and varied definitions.

For 'creativity', we adopt the definition proposed by Plucker, Beghetto and Dow, which was based on a meta-analysis of definitions from 90 refereed journal articles [8]:

> Creativity is the interaction among *aptitude, process, and environment* by which an individual or group produces a *perceptible product* that is both *novel and useful* as defined within a *social context*.

The first point to note about this definition is that it is not merely aptitude, process or environment in isolation that 'causes' creativity, but rather that creativity increases through the interaction of these three attributes. The authors note that they chose the word aptitude specifically because it refers to "a more dynamic characteristic or skill-set that can be influenced by experience, learning and training." [8]. From an educational perspective this is important, as it implies that although perhaps creativity cannot be 'taught' in the traditional sense of acquiring specific knowledge, learning can influence one's creativity. The other attributes, process and environment, are also ones that can be influenced in an educational setting. We can introduce students to processes and environments where creativity is encouraged.

The second point of the definition is that the output or result of creativity is a perceptible product. While the authors treat this more as a test of observability, it also fits well with the notion of using creativity for entrepreneurial pursuits, as it suggests it's not enough to merely have a good idea, but it must be realized into a tangible form. This also aligns with the definition of the term innovation we will consider shortly.

The third and fourth points about our adopted definition of creativity are that the output that is produced is both novel and useful, but this novelty and utility apply within a specific social context. Again, this definition fits well with entrepreneurial pursuits. It is not sufficient for an idea to be just novel, but it must serve a purpose and provide utility (and value) for an intended audience.

2.2 Innovation

For 'innovation', we use the definition proposed by Baregheh, Rowley and Sambrook, which was derived from analysis of 60 distinct definitions from literature covering a broad range of disciplines including technology, science and engineering [1]:

> Innovation is the multi-stage process whereby organizations transform ideas into new/improved products, service or processes, in order to advance, compete and differentiate themselves successfully in their marketplace.

The authors also identified six attributes that feature in common definitions of innovation, which we consider here in comparison to the definition of creativity described earlier. The six attributes proposed by Baregheh, Rowley and Sambrook [1] are named below, with short definitions followed by a comparison to the proposed definition of creativity by Plucker, Beghetto and Dow [8]:

- *Nature of innovation*: this refers to the notion of an innovation being something 'new or improved'. This relates to the creativity definition that the creative output should be "both novel and useful".
- *Type of innovation*: the type of output, e.g. a product or service. The definition of creativity refers to creating a "perceptible product" – again both definitions are clear that there must be an observable outcome.
- *Stages of innovation*: refers to a process that results in an innovation, e.g. starting from idea generation and ending with commercialization.
- *Social context*: Both definitions agree that creative outputs, or innovations, exist within a social context and that their value is measured by the specific stakeholders for which the output is created.
- *Means of innovation*: necessary resources, e.g. technical, creative or financial. This is referring to the inputs required for innovation to occur.
- *Aim of innovation*: the overall result to be achieved through innovation. The definition of creativity does not address this – the bigger question of why individuals or organizations should be creative.

There is considerable overlap between the definition of creativity proposed by Plucker, Beghetto and Dow [8] and that of innovation proposed by Baregheh, Rowley and Sambrook [1]. They both talk about creating something new, improved, novel and useful. They are both clear that there should be a tangible and observable output. They both acknowledge that there are processes that can assist in creating these outputs, and they both recognize the importance of social context, as a context in which creativity or innovation can occur, and as a context in which the resulting output exists. The only significant difference is that the definition of innovation addresses the additional question of why an organization would want to do this, specifically "to advance, compete and differentiate themselves".

2.3 Educational context

We have provided definitional contexts of creativity and innovation, so now we consider the specific computing curriculum context in which this work sits.

This paper discusses an experiment conducted over several years in an undergraduate subject on e-commerce. The subject is delivered as part of the information technology program at the University of Technology Sydney (UTS), and has the slightly unusual feature of having no academic prerequisites, meaning that it accepts students in first year through to final year of their studies. It also means students from other disciplines can choose the subject as an elective. E-commerce is a topic that has

elements of both business and technical study, and the subject discussed here does include both, making it appeal principally to IT and business students. The student numbers and ratio of disciplines is illustrated in Table 1 for the three years when this study was conducted. The percentages do not total 100% because there were a few students who were studying neither IT nor business degrees.

Table 1: E-commerce enrolment numbers

Year	Total enrolments	IT	Business
2014	143	83%	12%
2015	87	77%	11%
2016	107	79%	19%

The e-commerce subject has run for many years, however prior to 2014 students learned the theory behind e-commerce, some of the technical enablers for e-commerce (e.g. various internet and web technologies), and case studies of successful e-commerce businesses. In essence, it was a subject about the history of e-commerce to date.

From 2014 onwards, the subject was changed to incorporate a substantial element focusing on e-commerce innovation, i.e. the creation of new or improved online or mobile products, services or processes that are novel and useful in a defined social context. The subject still retained some elements of the history and case studies from its former incarnation to provide a balance between looking at the past, present and future of e-commerce innovation.

It is worth noting that developing creative thinking is not explicitly mentioned as one of the subject's learning objectives. One of the objectives relates to innovation, in that by the end of the subject, students should be able to propose future directions or innovations for a business or industry sector using e-commerce. The other learning objectives relate to developing expertise in e-commerce technology, stakeholders, and broader social, ethical and legal aspects. Thus, this was not pitched as a 'creative' subject, but rather a subject exploring the topic of e-commerce through both a future-focused lens (developing innovative e-commerce approaches) and a historical lens (studying the history of e-commerce to date). This paper focuses on the innovation components of the subject, although there were also additional online modules covering e-commerce technology, business and societal topics.

3 APPROACH

In the delivery of the e-commerce subject, four factors were considered with regard to their potential impact on students' creativity and innovation. The factors examined are:

Approach and methods for innovation

One of the topics added to the subject was to introduce students to design thinking [2] as an approach and a collection of methods or tools that are associated with different aspects of creativity and innovation. This was to address the 'process' element mentioned in the definitions of creativity and of innovation described earlier.

Design thinking is a methodology and process that can be used not only for creative problem solving, but also for identifying or framing new problems. It encourages people who are not design professionals to adopt ways of thinking and practices from design to apply in their own contexts – including to design that which does not exist yet. There are several variants of design thinking as a process, but common themes that emerge include:

- A focus on human-centered design approaches, by understanding and empathizing with a user or customer to identify their needs even when they may not be able to articulate them;
- Ideating or brainstorming ideas, with techniques for moving past the obvious ideas to look for more innovative solutions;
- Prototyping ideas as physical artifacts that can be tested with the user/customer;
- Iterating multiple times, so it is not seen as a linear process, followed once.

In workshops, students engage in activities in teams that help them move through the different stages of the process, and introduce them to new individual methods to use as part of the overall methodology.

Many of the underpinning principles of design thinking are already found in HCI. It is the application of these principles to projects or problem-solving situations that are not traditionally design-oriented that has given rise to design thinking as a methodology in its own right.

Combination of block and online delivery

Prior to 2014, the subject ran in a fairly traditional mode, with weekly lectures and tutorial classes. From 2014, the approach changed to a blend of online learning and block classes, with students coming to day-long classes once near the start of semester, once in the middle, and once near the end. The face-to-face classes were used principally for workshop-style and group activities in developing the innovation component of the subject, while the former lecture content was replaced with a series of online lectures and quizzes completed out of class time, covering the historical perspective of e-commerce. The intention of using whole-day workshops rather than weekly classes was to create an environment more akin to a creative studio or even a hackathon style of environment where students become immersed in their ideas and process, and have extended time to collaborate with their peers.

Instructor as a coach/mentor

With the change in delivery from standard lectures to block and online delivery, the role of the instructor also changed. No longer was there the need to stand in front of the class and deliver lectures as these were prerecorded as videos and made available online. Instead, the role of the instructor changed to

being one of a coach or mentor, helping teams of students to develop their ideas in a project-based learning style of delivery.

Classroom and environment

Although it was not originally intended to study or evaluate the physical space in which the classes were held, after trialling the new style of delivery in 2014 it became apparent that the physical space used for the classes did have an impact on how students felt in relation to their ability to be creative and/or innovative.

While the intent of each of these four factors was to create an overall situation conducive to students' creating innovative ideas, individually they are not unique to the computing curriculum. Design thinking is one particular methodology for problem framing and problem solving, but other computing courses might introduce students to agile or other methodologies that play a similar role in shifting thinking, but in different contexts. Block mode and blended delivery models are also not unique on their own, but are often used to suit students' attendance patterns (such as those working full-time) rather than a design choice. Coaching and mentoring are well established in project-based subjects. And it is also no surprise that different classroom spaces encourage different student behaviours, not just in this subject, but in any.

While it might have been preferable from a research perspective to isolate each of these factors and test them independently, the four factors were interrelated, leading to their use at the same time and corresponding interplay. The change to block classes was connected with the adoption of design thinking as a methodology, allowing students to iterate through multiple cycles of their ideas throughout a day, rather than having to interrupt their work and resume the following week. The change to a project-based learning style in class (again as implied through design thinking), changed the role of instructor to one of coach/mentor. The factor least connected to the others is that of the classroom environment, as this emerged as a factor based on experience rather than being a subject design choice.

In 2014, data was collected on hardcopy survey forms completed at the third and final block class of the semester. In 2015 and 2016, the primary method used for gathering data was an online survey questionnaire, answered by students 1-2 months after they had completed the subject. In both cases the survey was completed anonymously. The method of data collection changed after it became apparent from the 2014 results that students needed time to reflect on their answers. While collecting survey data online later resulted in fewer responses, the quality of the responses in the open-ended questions was much higher.

Some of the questions relevant to this study are shown below. Each one has a number that is used to identify it later in this paper, although this does not necessarily correlate with the sequence in which the questions were presented in the survey.

- Q1: Before commencing the subject, to what extent would you have considered yourself 'creative'?
- Q2: Before commencing the subject, to what extent would you have considered yourself 'innovative'?
- Q3: After completing the subject, to what extent do you feel empowered to propose new ideas in your study or work that are considered innovative?
- Q4: Which of the following statements best summarizes your opinion about creativity, after completing this subject? (with choices including that it is a trait some people are born with, it is a choice, it is a skill that can be improved through learning, it is a trait that everyone possesses, but some choose to use more than others)
- Q5: The subject used a 'coaching' style in the workshops. How did you feel about this coaching style of education compared with what you may have experienced in other subjects?
- Q6: What were some other differences that you found between the way this subject was delivered and other subjects you have experienced?
- Q7: To what extent do you think creative problem solving is relevant to information technology?

In addition, there were questions on demographics, and other open-ended questions related to improving the teaching in workshops that will not be considered here.

4 RESULTS AND DISCUSSION

Before discussing each of the four factors identified above, it is worth starting with the motivation. In Q7 above, students were asked "To what extent do you think creative problem solving is relevant to information technology?" The results over three years are shown in Table 2 (as scored on a 5-point Likert scale). Percentages of responses in each band are shown where 1 is 'Not at all relevant' and 5 is 'Very relevant'.

Table 2: Importance of creative problem solving in IT (Q7)

Year	1	2	3	4	5	Avg
2014	0%	0%	14%	19%	67%	4.52
2015	0%	0%	15%	23%	62%	4.46
2016	0%	5%	0%	25%	70%	4.60

The important message from these results is that students do understand the importance of creativity in relation to problem solving as a key skill for working in IT. There is no obvious trend over time. Yet while so much of our curriculum is dedicated to problem solving, there is less that focuses on creativity as a mechanism.

4.1 Approach and methods for innovation

The subject introduced design thinking [2] as a human-centered design approach for creative problem solving, and in particular, generating innovative ideas [9]. Design thinking is not new to the development of IT products and services – for example, it has been applied in mobile application design [4] and commercial software development [6].

One of the useful aspects of design thinking is that it focuses on the early stages of an innovation process – from understanding the user through to creating and testing a prototype of an idea. It does not attempt to tackle the later stages of an entrepreneurial venture such as developing a business plan, seeking investors and launching a product into the market. It focuses on the more creative aspects of the innovation process, and as such was a good fit for the e-commerce subject described here.

Students were introduced to design thinking early in the first workshop in a shallow way. As the semester progressed, students delved deeper into particular modes or phases within design thinking, and began to learn different methods that applied in that phase. Many of these methods were based around workshop activities designed to spark creative thinking, and to help students realize that with the help of exercises and activities, it is possible to increase their aptitude for creativity.

The survey included some before and after questions, for students to reflect on their development. These questions were answered on a 5-point Likert scale as shown in Tables 3, 4 and 5 (referring to the question numbers in section 3 of this paper). Percentages of responses in each band are shown where 1 is 'Not at all' and 5 is 'Very'.

Table 3: Before subject – self-assessed creativity (Q1)

Year	1	2	3	4	5	Avg
2014	6%	8%	57%	26%	3%	3.11
2015	0%	17%	67%	16%	0%	3.00
2016	7%	11%	56%	22%	4%	3.04

Table 4: Before subject – self-assessed innovation (Q2)

Year	1	2	3	4	5	Avg
2014	8%	14%	47%	23%	8%	3.08
2015	0%	11%	50%	39%	0%	3.28
2016	11%	19%	48%	15%	7%	2.89

Table 5: After subject – self-assessed empowerment to be innovative (Q3)

Year	1	2	3	4	5	Avg
2014	6%	13%	19%	55%	7%	3.42
2015	0%	0%	38%	62%	0%	3.62
2016	5%	5%	10%	70%	10%	3.75

Comparing Tables 4 and 5, at the end of the subject, students self-reported that they felt slightly more empowered to propose innovative ideas (Q3, Table 5) than they considered their capacity for innovation at the start of the subject (Q2, Table 4). Beyond self-reporting, there was no attempt to measure objectively whether they were more innovative, as there was no baseline task at the beginning of the subject.

In 2016 the increase was largest, as the way the workshops were delivered had by that stage been refined twice based on student and staff feedback. After the subject, students most commonly felt 'a little more' empowered to proposed innovative ideas (4 on the Likert scale), which is to be expected, given that this was one subject out of a whole degree program.

By the end of the subject, students generally also understood that creativity is not a trait that some people naturally have and others don't, but rather that it can be learned or unlocked through exercises and activities (Q4). In 2016, 53% of respondents felt that "Creativity is a skill, and people can learn to develop their own creativity", while 32% felt that "Everyone is naturally creative, but some people express it more than others". In contrast, only 10% felt that creativity is a trait that some people are born with and others aren't., and 5% felt that creativity is a choice.

In the open-ended questions, although students generally did not discuss creativity or innovation as aspects that set this subject apart from others they had studied, they were able to recall specific methods used in classes in relation to different phases of the design thinking approach. This is significant as in 2015 and 2016 the surveys were conducted 1-2 months after the subject had finished (when students were commencing their next semester).

This ability to recall specific methods increased over time from 2014-2016 as the subject was refined. One of the improvements made over the period was to be more explicit with students in highlighting the methods and connecting them to the design thinking approach so that students were able to better see the big picture.

4.2 Combination of block and online delivery

The mode of delivery of the subject changed at the same time that the subject focus changed to place more emphasis on innovation. The rationale for this change in delivery mode was twofold. First was the desire to move towards flipped learning approaches, and to free up face-to-face time for student collaboration and student-staff interaction rather than one-way information transfer typical of traditional lectures. This was a strong motivation for the online lecture delivery, but in itself did not necessitate block classes.

The second reason was that a block mode of delivery seemed to better suit the nature of the class activities. Teams could make greater progress on their ideas when they had whole-day classes to work on them, and the day could be interspersed with exercises and activities to help make progress. It also meant that student teams could bond with each other better due to the more intense collaboration.

Block classes were offered on both Fridays and Saturdays, with students able to choose which day they preferred (however they had to attend the same day each time to stay with their team). Not surprisingly, the Friday block classes tended to have a higher population of full-time students, while the Saturday classes had more part-time students, including those who were employed full-time.

Overall, this aspect of the subject divided the class. It seemed that the majority of students enjoyed the flexibility of completing the online modules at their own pace, and having fewer structured classes, especially those attending Saturday

classes. Other students provided feedback that the subject should go back to having regular weekly classes like other subjects.

On the positive side, student comments included:

- Being treated like adults and making it glaringly obvious the staff were there to help at any given moment
- The subject was delivered online and in block mode. This was good for students working full-time
- I enjoyed the block sessions it was easier to digest larger chunks of information and work in groups than in weekly attendance
- I enjoyed all online lecture content. Can study in own time and not be affect by my 1hr travel time to uni

On the negative side, comments included:

- No weekly classes which is terrible and because of that having to spend 7 hours at uni for that one subject
- I would prefer weekly classes as I find the whole-day classes tiring and sometimes overwhelming
- Go back to the way it used to be with weekly classes

Over the three-year period of this study, the nature of the block classes and online work evolved. In 2014, students were required to do weekly online activities based on that week's online lecture and readings. This was in addition to the ongoing project work that was being covered mainly in the block classes. Feedback from students from this year was that the workload expected was too high, and that there was a disconnect between the weekly activities and what happened in the block classes.

In 2015, the weekly online activities were removed (although students were still expected to view the online lectures and complete a short quiz). However, the class time was also changed so that it included some tutorial-style activities in class that were similar in intent to the previous online activities. This seemed to help students feel a better sense of connection between the online and face-to-face components of the subject.

Students were also given additional information and warnings before the subject commenced about the non-traditional delivery style, so they had the chance to opt out if they felt they would not enjoy the block delivery.

Overall, by 2016 the delivery mode seemed to be successful for most students, however this was one of the trickiest elements to get right.

4.3 Instructor as a coach/mentor

A third factor that changed was the shift from the academic staff delivering lectures to having the academic staff work alongside students in the role of coach or mentor. This is not uncommon for project-based learning subjects, which is what a substantial portion of the e-commerce subject has in essence become.

Because of the gaps of 3-4 weeks between face-to-face sessions, the lecturer and tutors were available to students for consultation/mentoring as they developed their ideas for innovative e-commerce products and services. In 2014, students were encouraged to make appointments for face-to-face mentoring, or to ask for feedback online, which led to a very low use of the service. From 2015, the mentoring time was structured as a drop-in session where students did not need to make an appointment, and it was more heavily promoted in class and online. This led to a greater number of students taking the opportunity to present their partially formed ideas for feedback, and to receive from mentors on how to improve.

What also became evident through this journey is that students were not accustomed to taking advantage of mentoring when it was offered. In other subjects which have weekly classes, it seems more common that the tutor defines the regular check-in points for students working on assignments or projects, whereas in this case there was more responsibility placed on the students to come and ask for feedback and direction when the team had something new to discuss or present.

When asked for feedback on the coaching style used (Q5 in section 3), students' reactions were mixed. One limitation of the survey design is that it did not ask students how many times they (or their team) met with a mentor between classes, therefore it is impossible to distinguish between responses from those students who did seek support and those who didn't. However, examples of positive comments included:

- The coaching style allowed more open-ended discussions and learning in small groups which I enjoyed much more than lecture and tutorials
- We were given instant feedback from tutors which was helpful
- Excellent. I liked the idea of being guided to a solution

On the negative side, comments included:

- This 'coaching' style did sometimes leave myself frustrated and lost, however I do agree it was something new to me
- This was the first time I've experienced coaching style. I didn't see anything different and quite frankly it was just another subject you would self-teach before the final exam

Another interesting observation about students' reactions to being mentored is that they were sometimes not equipped to deal with receiving different suggestions from different mentors. This caused frustration for a number of students, with comments like:

- Sometimes it felt that the lecturer and assistant would give different instructions
- I think majority of my team felt this assignment was overwhelming and frustrating. There were times when [lecturer] was absent and consultation was held by just [tutor] and vice versa and one tutor would be fine with a certain idea and then the next week at consultation one tutor would change their mind

Some students seemed to be seeking the 'right' answer from the mentoring process (or the answer that was likely to score the

highest marks), when in reality there was no single right or wrong answer. Mentors might make suggestions like 'Have you considered …?' or 'What might happen if you tried …?' Some students seemed to take these as directions they must follow (since they were offered by the teaching staff), which would naturally lead to frustration and confusion if they received different suggestions at different times.

Upon reflection, this frustration could be minimised by (a) making clearer to students the role of mentoring, and ensuring they understand they are still free to make their own design choices and do not have to do what the staff say; and (b) to better equip students with tools for dealing with conflicting advice or suggestions, such as frameworks for decision making that they can use to defend the design choices they make.

4.4 Classroom and environment

This final factor was not originally intended to be part of the study, until it became quite apparent that the physical room in which the classes were held, and the environment created, did play a significant role in how collaborative student teams were, and how this in turn affected how creative and innovative teams were during class time. In hindsight this is not surprising, and is a phenomenon observed by other authors [7,11]. As this was a factor identified after the fact, the evidence supporting it is more anecdotal or ethnographic in nature as students were not surveyed on this aspect of the subject.

In 2014, the classes were held in a fairly traditional university tutorial classroom. Specifically, the room was configured with rectangular desks, arranged in rows such that all students face the front of the classroom. The room itself was in an older style building and had not been renovated recently. The only IT or AV equipment in the room was at the front, for the instructor, and even WiFi access was poor due to its location. At the start of every class, students helped to arrange the desks into clusters for teamwork, and restored them at the end of class.

By contrast, in 2015 and 2016, the classes were held in a new, purpose-built collaborative-style classroom. Desks were shaped as rounded trapezoids, designed for 6-8 students to sit around, and both desks and chairs were on wheels. Each desk had access to its own built-in IT by way of a computer with large screen that could be shared by the table. The room arrangement had the instructor in the centre, rather than at the front – indeed, there was no 'front'. WiFi was good.

Observations of the teaching staff in the two scenarios noted that in the traditional classroom, even with the desks rearranged into teamwork clusters, students spent less time collaborating and more time working individually. In activities where students moved around the room (e.g. to view other teams' work), students would spend less time with each group and ask fewer questions. In the purpose-built collaborative classrooms, students reacted quite differently, spent more time engaged in active discussion, and were more comfortable moving around the room and sharing ideas with other teams.

Not surprisingly, this appeared to have an influence on teams' engagement during class time, which is supported both by inclusion of 'environment' as part of the definition of creativity used here (where environment includes, but is not only, physical environment), and by other research on the role of physical space in creativity.

While academic staff often don't have a great deal of choice over the classroom space available to them, in subjects where a project-based learning approach is used and in particular where the goal is to explicitly encourage creativity and innovation, having an appropriate space does make a difference to students' outcomes.

5 CONCLUSIONS

This paper examined four factors that were perceived to influence the outcomes of undergraduate students in a subject on e-commerce. Students were tasked with proposing an innovative e-commerce product or service, and in transforming the curriculum to address this, a range of other changes were introduced. The four factors which capture key curriculum changes were:

- Approach and methods for innovation
- Combination of block and online delivery
- Instructor as coach/mentor
- Classroom and environment

The definition of creativity proposed by Plucker, Beghetto and Dow [8] includes the "interaction among aptitude, process and environment". We found these characteristics to be very relevant. In the e-commerce subject, students were equipped with both a process and a series of methods or exercises for developing their aptitude for creativity. It was also observed that the environment (both physical environment and the balance of face-to-face versus online time) also influenced students' creativity.

As the definition states, it is the interaction between these that is important. A poor environment can have a negative impact even if students have both aptitude and process knowledge. A weak aptitude or knowledge of process in students can have a negative impact even if the environment is good. Being aware of the interaction among these three characteristics is important in educational settings where creativity is desired.

In summary, given the importance of innovation in today's society, especially in technology fields, there is a need to incorporate a greater capacity for innovative thinking in computing graduates.

Innovation is closely linked to creativity, as evidenced by the considerable similarity in their definition. While creativity does appear in computing curricula, it is often used for producing creative solutions to known problems, rather than identifying new problems to address. Thus, while computing graduates may be able to think creatively, they lack the distinguishing feature of innovation, namely to use that creativity to help organizations "advance, compete and differentiate themselves successfully in their marketplace" as defined in [1]. The approach presented here, of an open-ended design challenge with a problem-finding component, goes some way towards this goal, although it would be strengthened if done in partnership with an organization.

In considering the impacts on computing curricula, we should be equipping students with an aptitude, process and environment for creativity, together with an understanding of the purpose of innovation to generate new products or services to help organizations compete and differentiate (not merely solve problems). This paper has offered suggestions and pitfalls on doing so based on experiences over a three-year period of trialling and evaluating new approaches.

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