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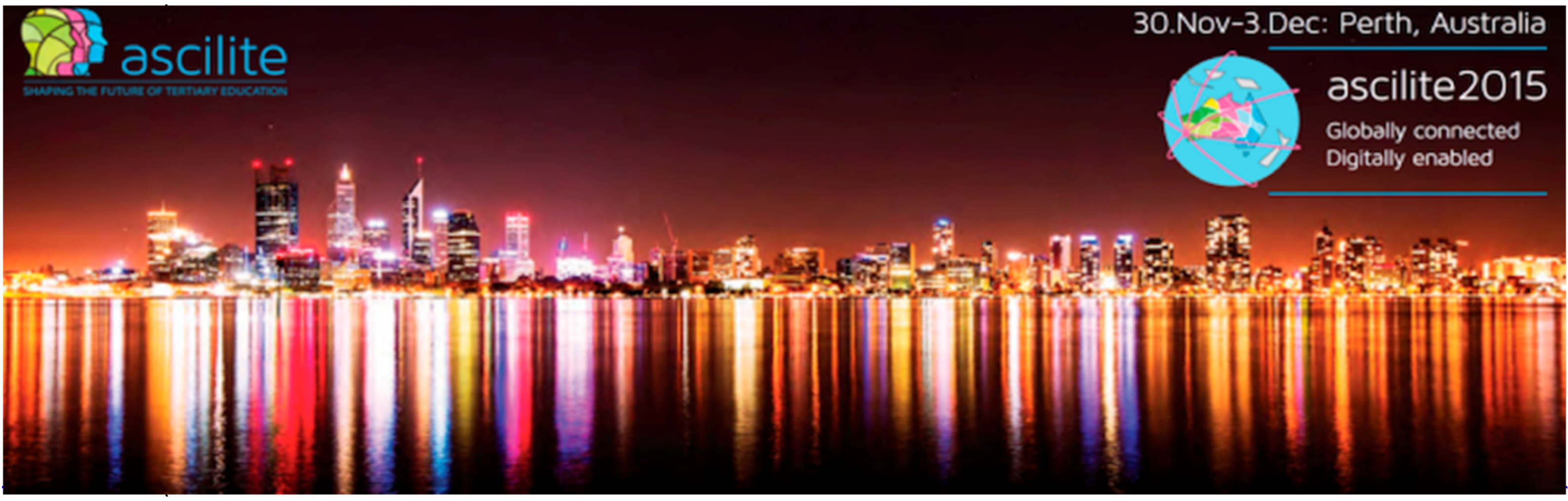

Investigating the effectiveness of an ecological approach to learning design in a first year mathematics for engineering unit

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This paper reports on the results of a project aimed at creating a research-informed, pedagogically reliable, technology-enhanced learning and teaching environment that would foster engagement with learning. A first-year mathematics for engineering unit offered at a large, metropolitan Australian university provides the context for this research. As part of the project, the unit was redesigned using a framework that employed flexible, modular, connected e-learning and teaching experiences. The researchers, interested in an ecological perspective on educational processes, grounded the redesign principles in probabilistic learning design (Kirschner et al., 2004). The effectiveness of the redesigned environment was assessed through the lens of the notion of affordance (Gibson, 1977,1979, Greeno, 1994, Good, 2007). A qualitative analysis of the questionnaire distributed to students at the end of the teaching period provided insight into factors impacting on the successful creation of an environment that encourages complex, multidimensional and multilayered interactions conducive to learning.

Keywords: ecology of learning, affordances, blended learning, probabilistic learning design

Introduction

Modern higher education is facing the challenge of assisting university students to develop 21st century-specific skills such as transmedia navigation, critical thinking, problem solving and creativity. This challenge necessitates an innovative approach to learning and teaching, one that combines recent advances in research on human cognition, perception, acquisition, learning and teaching with the institutional requirements of preparing graduates for the rapidly changing modern world. What would be the best way of describing this modern, dynamic and complex environment? Within the context of higher education, the term "knowledge-based economy" (Powell and Snellman, 2004) emphasises the role of humans' cognitive skills and capabilities in advancing technological and scientific progress on unprecedented scale. However, the rapidity of these changes makes them equally quickly obsolete, which in its turn, creates a need for more discoveries and progress. This constantly changing nature of knowledge-relying professional environment requires constant upskilling, therefore learning. George Siemens described this phenomenon in terms of "perpetual learning" (Siemens, 2015). According to the researcher, current students are facing 40 years of learning (rather than 4), at different levels and focused on developing/ mastering different skills. So this raises the questions: how are we to assist learners with the development of skills allowing them to perpetually learn? How are we to prepare them for the challenges of this new type of economy – a learning economy?

To successfully face the above-mentioned challenges, modern higher education institutions need to take a more holistic approach to designing, developing, implementing and evaluating students' learning experiences. Technology-enhanced learning (Laurillard et al., 2009) offers a research paradigm able to inform the "design for learning" (Goodyear and Carvalho, 2013 p. 49), the pedagogical approach applied by people to facilitate other people's learning by "working with networks of interacting digital and non-digital entities" (Goodyear and Carvalho, 2013, p. 49). Such an ontological position implies an ecological worldview on learning and teaching processes, one that is interested in studying a complex network of multilayered interactions and resulting interdependencies between all constituents of the environment occurring at all levels of interaction: physical, social and cognitive.

Mindful of the above-mentioned critical considerations, the researchers adopted a probabilistic (as opposed to the classical, causal) approach to learning design (Kirschner et al., 2004). More precisely, the researchers undertook the task of creating a "world of learning" (Kirschner et al., 2004, p.25), a specific, technology-enhanced learning and teaching environment that provides opportunities for complex, multilayered and multidirectional interactions between all constituents of the environment (i.e. virtual networks and social agents). This type of environment encourages learning processes by providing various opportunities for action. In short, the researchers' intent was to create an environment that would be cohesive and coherent on one hand and would foster the complexity of interactions on the other.

This study investigated if a cohesive, coherent and engaging technology-enhanced learning and teaching environment created by the researchers was successful in promoting learning. A first-year mathematics for engineering unit offered at a large, metropolitan Australian university was chosen as the context for the research. The researchers redesigned the unit to embed flexible, e-learning and teaching experiences within formal and informal settings. The research design focused on investigating the effectiveness of the technological, social and educational opportunities for action, or affordances, (Laurillard et al. 2000; Kirschner, 2002; Kirschner et.al, 2002, 2004; Good, 2007; Czaplinski, 2012; Czaplinski et al. 2015) offered by the created environment. Data were collected through a paper-based questionnaire distributed to students at the end of the teaching period. The questionnaire evaluated the effectiveness of the redesign by looking at students' perceptions of achieving learning outcomes, satisfaction with the unit's organisation (cohesive and coherent environment) and teaching approaches, and finally, student engagement with the unit content. In their initial hypothesis formulated at the beginning of the project, the researchers assumed that by creating cohesive and coherent environment that provides multiple and various opportunities for action (including deep engagement with knowledge), the learners will engage in complex and meaningful relationships with both human and non-human constituents of the environment, and in this way will adopt a deep approach to learning. The specific research questions were:

1. What were students' perceptions of achieving unit learning outcomes?
2. To what extent were students satisfied with the unit organisation?
3. To what extent were students satisfied with the unit delivery?
4. To what extent were students engaged with the unit content?

The data analysed through the theoretical lens of the notion of affordance (Gibson, 1977, 1979, Greeno, 1994, Good, 2007; Czaplinski, 2012; Czaplinski et al., 2015), allowed the researchers to shed light on the ways the learning process was mediated by the specifically designed technology-enhanced environment within formal and informal settings.

Technology-enhanced learning

Relationships, context, emergent patterns, quality, value, critical perspective, diversity and agency are major characteristics of an ecological approach to learning (van Lier, 2010). Together, they pose three important challenges to technology-enhanced learning. First, they require the creation of networks, both human and virtual. Second, the virtual networks need to become a platform for interaction between digital entities, i.e. electronic systems, and non-digital entities, i.e. social agents taking part in the learning and teaching processes. Third, in order to foster learning, they require active engagement happening at various levels, the highest being meaningful and deep engagement with knowledge, (Marton & Säljö, 1976; Entwistle, 1981, 2000, 2009; Ramsden, 1992; Biggs &Tang, 2007), the *sine qua non* of understanding.

All these challenges emphasise the interplay between non-digital and digital constituents of technology-enhanced learning. They both form an entity, they interact with each other, their relationship is bidirectional, hence they both need to be investigated in parallel, since "there is no person without environment and no environment without a person (or organism) dwelling in it" (Goodyear and Carvalho, 2013, p. 50). Such an ecological perspective on human cognition sees acquisition of knowledge as a process taking place outside of the individual (van Lier, 2000; Fettes, 2003, Czaplinski, 2012). It can be described in terms of a constant, dynamic, labile, and diachronic interaction, a type of discovery of an individual's world through his/her cognitive tools (Reed, 1996; Fettes, 2003; Czaplinski, 2012). This mutualist point of view, one in which "mind, body and environment cannot be understood in isolation, but are constructions from the flow of purposive activity in the world" (Good 2007, p. 269), has important consequences for theory of learning, learning design and development, especially within technology-enhanced learning and teaching environments. The environment shapes learner's knowledge as much as the learner shapes his/her environment. Therefore, the provision of opportunities for learning, their quality, learners' capability and readiness of perceiving them, the decision of taking or not taking them up and the capacity of adapting them to learners' individual needs become crucial, interdependent constituents of ecological contexts.

The acts of cognition, acquisition and learning are based on complex learners' interactions with the environment, constant discovery and (re-)negotiation of meanings embedded in the environment (van Lier, 2000). Such duality necessitates flexibility of the learning design. On one hand, the ecological worldview requires the learning design to consider learners' identities and to encourage their agency with the purpose of enhancing their motivation. On the other hand, the learning design should also assess technology for its capability of providing rich and (good) quality learning experiences. For TEL to be effective, educators, developers and designers need to shift attention from individual aspects of the environment and adopt an all-inclusive approach, one that encompasses the characteristics, particularities (and preferably even idiosyncrasies) of both, digital and human constituents allowing all social agents of the educational process (e.g. students, lecturers, tutors, developers, designers, visiting lecturers, etc.) to adapt to the environment. The important question is "how?" How to identify the above-mentioned opportunities, how to make sure they will be perceived by social agents and how to ensure their effective (educationally beneficial) use. Laurillard explained these challenges in the following way: "our perspective is […] oriented towards the role of technology to enable new types of learning experiences and to enrich existing learning scenarios. To do this successfully, we have to understand not just teaching and learning, but also, the context in which the implementation of technology-enhanced learning (TEL) has to take place" (Laurillard et al., 2009 pp. 289-290).

Research context and methods

The current paper reports on the final stage of a three-semester long project, focusing on successive deliveries of the same, first-year mathematics for engineering unit. This unit is a foundational subject that provides the mathematical knowledge and skills that underpin later engineering studies. The mathematical content includes topics such as functions, complex numbers, calculus, matrices and vectors. The unit has faced several challenges, such as high teaching team turnover, and a diverse range of teaching and pedagogical styles. These included teacher-centred methodologies, characterised by transition-focused lecturing, allowing for limited collaborative learning, drill-focused workshops, and basic use of online tools. The diverse student cohort has posed a double challenge to teaching staff. First, significant discrepancies with mathematical knowledge and skills between students enrolled in the unit have caused some students to experience a sense of being "out of place" and feelings of frustration with unsatisfactory learning progression. Some students reported a sense of confusion as it appeared they lacked a clear understanding of the relevance of the unit to their particular engineering degree. The resultant unit evaluation completed by students indicated a low satisfaction rate and low progression with a reasonably high failure rate forcing many students to repeat the unit. Table 1 summarises the diversity of student cohort based on the degree-type.

Table 1: Diversity of student cohort based on field of degree (N=130)

Degree	Number of students enrolled
Engineering, including: mechanical, civil, electrical, power, telecommunications, aerospace/avionics, medical, mechatronics.	92
Science, including: physics, astrophysics, biology, public health, environmental sciences, chemistry, mathematics, geology.	13
Double degrees, including: engineering/information technology; business/engineering;	14
Information systems	1
Visiting students (High School students)	9
Visiting students (international exchange)	1

In the initial phase of the project, the researchers defined three design principles which constituted the basis for scoping research questions. First, technology needed to be used to create an overarching environment, one that would be easily accessible and would provide all involved with opportunities to connect, regardless their status (learners, educators, learning support), physical location or technological savviness. Second, technology should serve as a catalyst for learning. By interacting with other social agents, and with the technological tools, through and within the technology-enhanced environment, social agents' attention should be diverted towards the opportunities for learning. That is, while educators' attention should focus on making the opportunities for learning salient to students, students' attention should be diverted to perceiving and taking up (or consciously rejecting) multiple affordances for learning. Third, the environment should foster student engagement by providing a platform for blending different educational approaches (e.g. individual learning, collaborative learning, flipped learning) and in this way support the acquisition of knowledge and skills.
The above-mentioned principles were enacted in different ways. These new ways included changes made to the online platform, teaching methods, and the inclusion of a learning support team in the unit delivery.

Building on the principles of probabilistic learning design (Kirschner et al., 2004), the researchers redesigned the unit with the intention to create a truly blended educational experience. The authors designed technology-enhanced, modular learning and teaching environments that blended physical and virtual spaces into a cohesive and coherent entity. The physical modules included lectures, and workshops and were complemented with the virtual components encompassing pre-lecture videos, WeBWorK (an online testing tool capable of appropriately representing mathematical problems and analysing algebraic responses for correctness), and additional learning resources in the form of contextualised, applied and motivational problems to be used during face-to-face contact hours (named "challenge questions"). In addition, a series of learning support activities, delivered by the university's mathematics learning support team, was included in the design. The (re-)design principles, were anchored in research within learning design (Kirschner et al., 2004), blended learning (Partridge et al., 2011; Saliba, et al. 2013) in the context of mathematics courses (Stevenson and Zweier, 2011; Calderon, et al., 2012; Carbonell, et al., 2013; Czaplinski et al., 2015) and also tested the effectiveness of an emerging instructional approach of flipped learning (Abeysekera and Dawson, 2015; Estes, Ingram and Liu, 2014; Hamdan et al., 2013; Herreid and Schiller, 2013; Jamaludin and Osman, 2014; Willey and Gardner, 2013).

The changes were introduced sequentially over three semesters, starting from summer semester of 2013 until semester 2, 2014. One of the important elements in creating the "world of learning" was to design a learning platform that would reflect the underpinning philosophy of an ecological approach emphasising cohesiveness and coherence of the environment. A platform that would provide a logical, smooth, and straightforward connection between particular virtual modules and, at the same time, would graphically represent the connection between the virtual and physical modules. To this end, the authors analysed technological affordances offered by Blackboard, the standard Learning Management System used at the university. The intention was to identify the affordances offered by the system to identify multiple and varied options to facilitate learners' perceptions. By providing multiple means of representation, the environment would cater for different types of learners, maximise the opportunities for perceiving the overall organisation of the unit and in this way optimise the opportunities for learning. It was thought that this would result in higher student satisfaction with the unit design and delivery and better engagement with knowledge. Figures 1 and 2 below show the final design of the platform.

Figure 1: Blackboard site screenshot top of the page

Figure 2: Blackboard site screenshot bottom of the page

3	4 Aug	Topic: Complex numbers Pre-class videos [V1 | V2 | V3 | V4 | V5] Slides for videos [V1 | V2 | V3 | V4 | V5] Annotated slides for videos [V1 | V2 | V3 | V4 | V5] Lecture scribbles [Tues | Thur] Lecture videos [Tues | Thur]	Workshop activity Complex numbers worksheet and answers Exercise sets from Mallet et al (Complex numbers)	
4	11 Aug	Topic: Complex numbers No new pre-class videos Lecture scribbles [Tues | Thur] Lecture videos [Tues | Thur]	Workshop activity Complex numbers worksheet and answers Exercise sets from Mallet et al (Complex numbers)	PST Part 1 due Friday 15th 9.45pm (via Assignment Minder)

Three alternative and complementary visual display means were utilised, providing rich stimuli for perceiving opportunities for different types of actions, namely: 1. Clickable images representing interconnected balls forming a cycle, 2. An interactive unit map, and 3. Clickable tabs. The clickable image emphasised the nature of the activities. The researchers intended to present to students the image of an all-encompassing structure, composed of virtual (“How am I travelling?”, “Online consultations”), in-class (“Workshop/tutorial”, “Lecture”, “Problem-based activities”) and out-of-class opportunities for learning (“STIMulate session” – university sponsored, co-curricular learning support initiative featuring weekly academic-led workshops as well peer-led support for mathematics). This visual representation also reinforced the student-centred approach, harmoniously encompassing interconnected (and interdependent) modules. The tabs, located to the left, played a functional role. Associated with the standard design of the Blackboard site, the tabs were there for those students who would feel lost facing an unexpected design of the site. The tabs also provided additional opportunities for action, such as communication (“Announcements”), as well as emphasising important unit elements (“Assessment”). In this way, information about this part of the unit’s content was displayed using a variety of visual supports, optimising the opportunities for being perceived and accessed. Finally, the clickable unit map not only represented a chronological ordering, assuring students of the orderly, well-planned organisation of the unit, but most importantly clearly provided unit contents (pre-lecture videos presented sequentially, broken down into “steps” within each weekly module, complemented by additional resources and, again assessment details).

The design of the Blackboard, Learning Management System encapsulated pedagogical principles underpinning the redesign of the unit. It provided learners with multiple and diverse occasions for perceiving opportunities for learning taking them up and enacting them through meaningful engagement with content (educational affordances), technological tools (technological affordances), and co-construction of knowledge in collaboration with other students and academics (social affordances).

Data collecting involved using mixed methods (quantitative and qualitative) (Hopkins, 2002; McNiff and Whitehead, 2002) administered to students in the form of a paper-based questionnaire at the end of the semester. The questionnaire was designed to provide answers to the above-mentioned research questions focusing on the effectiveness of the design. The questionnaire used a combination of structured (i.e. Likert-scale, open/closed), and unstructured questions (i.e. open comments). The responses were evaluated through the theoretical lenses of the notion of affordance (Laurillard et al. 2000, Kirschner et al., 2002, 2004; Good, 2007; Czaplinski, 2012; Czaplinski et al., 2015), allowing discovery of learners’ patterns of behaviour, hence testing the effectiveness of the created “world of learning”. More precisely, once the survey responses collected, the data were organised in tables, showing numerical representation of students’ responses. Additionally, students’ comments were consulted to clarify/ provide insight into the conclusions drawn from numerical data. To assure the accuracy of the conclusions drawn from qualitative data, quantitative data on student satisfaction and student engagement with Blackboard Learning Management System were collected.

The quality of the learning experience is a condition of achieving educational excellence. It depends on the ways within learners’ unique environments, that means the characteristics of a particular cohort, are established, their learning needs identified and catered for, using tailored approaches. This requires educators not only to be aware of their own and learners’ attributes as well educational environment characteristics, but also to be able to analyse them from the perspective of their effectiveness in fostering excellence (Czaplinski, 2012). The concept of affordance offers a theoretical lens for such investigation.

Findings and discussion

The researchers used a psychological perspective on the notion of affordance (Gibson, 1977, 1979; Good, 2007), which can be explained in terms of a unit of analysis composed of an opportunity for action "nested" (Good, 2007, p. 277) within a functional context. Functional context, or nested in the frame of reference, triggers the act of perceiving an opportunity for action. Frame of reference influences the way how the environment is perceived (including the opportunity) and impacts on the decision to take it up (or not). In its entirety, the three layers form an affordance. Such an interpretation stresses the importance of all constituent 'layers' of the concept and emphasises their interdependencies. However, not all affordances are of the same nature. Following from the work of Kirschner et al., (2002, 2004), the researchers investigated the perception and uptake of three different types of affordances: 1. technological, understood as properties of the object that make it easy to use, 2. social, defined as the properties of the environment that encourage social interaction, and 3. educational, understood as the properties of a particular pedagogy applied to a particular cohort of learners within a particular environment (2004, p.28).

The first research question investigated students' perceptions of achieving learning outcomes. The researchers' objective was to reveal , within the created environment, if students perceived their learning as successful in terms of academic achievement. Or, seen from the theoretical background, if the stimuli embedded in the functional context successfully encouraged the uptake of educational affordances. The researchers assumed that the positive perception of academic achievement results from the uptake of affordances offered by the environment. This might suggest that the interaction between the learner and the environment was conducive to construction of new knowledge. Although this does not directly imply deep learning, there are premises (student satisfaction, perception of achievement) indicating that deep learning might have taken place. The table below summarises the responses of participating students.

Table 2: Summary of questionnaire responses to research question 1 (N=39)

I believe that I am better at:	Agree	Neutral	Disagree
… understanding and interpreting mathematical notation	30	9	0
… recognizing, manipulating and solving mathematical expressions	33	6	0
… understanding and applying elementary functions, their derivatives and integrals, complex numbers, matrices and vectors	29	9	1
… employing mathematical techniques to solve elementary problems provided in an engineering context	26	10	3

The responses clearly indicate high level of students' positive perception of their academic achievement . This observation is confirmed by the results included in Student Evaluation Reports, standard evaluation tools, namely "Pulse" collected in the first half of the semester and "In Sight", focusing on overall student satisfaction and conducted at the end of the semester. The two figures below present the summary of students' satisfaction. The scale ranges from 0 to 5, with units scoring below 3 considered low performing and those scoring above 4 seen as highly performing.

Figure 3: Pulse Student Feedback Results

Pulse Student Feedback (no results shown for <6 enrolled)

>4.0 Unit Rating | <3.0 Unit Rating

Year	Teaching Period	Total Surveyed	Total Responded	Question Text	Rating
2014	2014-SEM-2	161	19	This unit is providing me with good learning opportunities. (PS1)	4.2
				I am taking advantage of opportunities to learn in this unit. (PS2)	4.1
				I am satisfied with this unit so far. (PS3)	4.1

Figure 4: In Sight Student Feedback Results

Insight Student Feedback (no results shown for <6 enrolled)

Year	Teaching Period	Total Surveyed	Total Responded	Question Text	Rating
2014	2014-SEM-2	130	15	This unit provided me with good learning opportunities. (IS1)	4.7
				I took advantage of the opportunities to learn in this unit. (IS2)	4.1
				Overall, I am satisfied with this unit. (IS3)	4.4

Based on these comments, the researchers concluded that the unit successfully engaged students into learning by creating an appropriate environment. Furthermore, this means that the researchers' and students' perceptions of the educational affordances offered by the created environment coincided. Analysed from the notion of affordance, this signifies that the frames of reference of both types of social agents strongly overlapped with regards to understanding what technology-enhanced learning environment should look like in order to be successful in fostering learning. Moreover, it seems that the functional context (actual activities triggering action) appeared to be effective in fostering students' learning. From the questionnaire responses the researchers conclude that students' perception of achievement was influenced not only by an appropriate environment; it was also triggered by teaching methods applied during the semester.

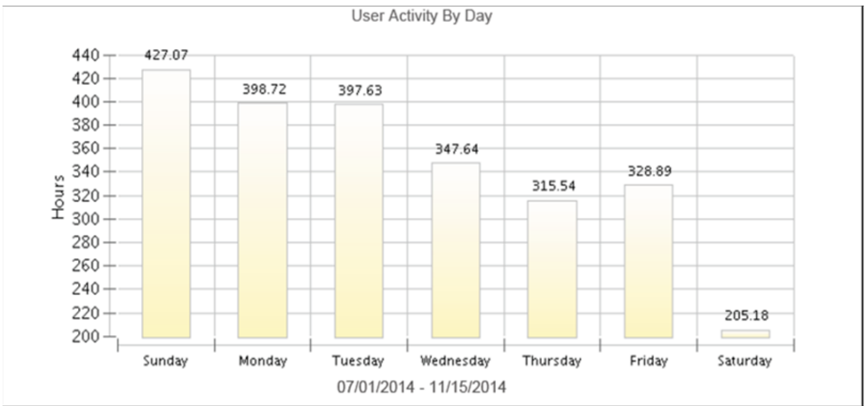
Responses to the second question confirm the above conclusion. As already mentioned, the unit adopted a modular structure that blended physical and virtual spaces into a cohesive and coherent entity. One of the crucial, and most difficult, parts of the design was the assurance of connection between both types of modules. The most significant challenge was making sure all components were appropriately "blended". The responses indicated that this objective has been achieved. Table 3 summarises the responses.

Table 3: Summary of questionnaire responses to research question 2 (N=39)

Question	Agree	Neutral	Disagree
The unit was well organized.	33	5	1
I could see clear connections between pre-lecture videos, lectures, workshops, STIMulate sessions and online practice quizzes.	33	6	0

It is important to note that the results imply students' high satisfaction with the coherent and cohesive nature of the environment. Students' comments confirm this conclusion. One student wrote: " This was one of the best organized units that I have done, which really helped my learning". In addition, the data on user activity provided by Blackboard Learning Management System shows patterns of behavior suggesting high activity rate maintained almost throughout the whole week, and this for the duration of the semester. The figure 5 below illustrates this observation.

Figure 5: User activity by day throughout the semester



The pattern of daily activity correlates with the timetable of the unit, with Lectures scheduled for Tuesday (2 hours) and Thursday (1 hour), and Workshops being run on Tuesdays after the Lectures and Wednesdays. It seems that students took the opportunity for engaging with the content through the LMS on a fairly constant basis, with activity happening not only on days of the contact with lecturer/ tutors (Tuesday, Wednesday and Thursday), but also on days when there was no direct contact with the teaching team, including Sunday.

While the first two questions primarily focused on the role frames of reference played in making the environment successful, the third research question explored the role functional context played in triggering action, i.e. uptake of the three identified types of affordances (educational, social and technological) . To gain insight into this question, the researchers asked two types of questions investigating: 1. the delivery and 2. the ways students used the online tools. Table 4 summarises the responses. “E” signifies educational affordance and “S” stands for social affordance.

Table 4: Summary of questionnaire responses to research question 3, focus on delivery (N=39)

Question	Agree	Neutral	Disagree	No response
Pre-lecture videos helped me with understanding the lecture content.(E)	38	1	0	0
During lectures I could apply the information from the pre-lecture videos to understand the theory being presented. (E)	35	3	1	0
The lectures were taught in the way that allowed me to engage with: the material (E) my colleagues (S) my lecturer/ tutor (S) STIMulate support (S)	36 22 31 16	2 17 8 20	1 0 0 3	0 0 0 0
The workshops helped me to see how the mathematics relates to my other studies. (E)	25	10	2	2
I found the contextualised, applied and motivational problems used to link lectures and workshops useful for my engagement. (E)	25	12	1	1
These contextualised, applied and motivational problems allowed me to apply the theory covered in the lectures to practical uses in workshops.(E)	32	4	2	1
The workshops were taught in a way that allowed me to engage with: the material (E) my colleagues (S) my lecturer/ tutors (S) STIMulate support (S)	32 28 29 15	5 10 8 21	2 1 2 3	0 0 0 0

The questionnaire responses demonstrate high satisfaction rate with the delivery methods. Engaging, providing strong connections between theoretical (pre-lecture videos, lectures) and practical modules (workshops) and expansions (contextualised, applied and motivational problems), they proved excellent trigger for assisting student in perceiving two types of affordances (educational, social) and successfully taking them up. In other words, not only it provided appropriate, complex stimuli, but it also successfully made them salient to learners in a way that majority of respondents perceived and took the affordances up. This is confirmed by the following comment made by a student in an open-ended section of the survey: “I found workshops were really beneficial as we got to work on a number of examples and developed a deeper understanding of the subject matter”.

As for the remaining technological affordance, it was investigated closely with the next question, focusing on the ways the tools were used in the unit. Table 5 summarises the responses. “E” signifies educational affordance, “S” stands for social affordance and “T” relates to technological affordance.

Table 5: Summary of questionnaire responses to research question 3, focus on online tools (N=39)

Question	Agree	Neutral	Disagree	No response
Online diagnostic:				
was easy to use (T)	13	20	4	2
helped me with practicing the theory (E)	22	11	4	2
results motivated me to seek external help (such as tutor, peer STIMulate) (S)	15	17	5	2
quizzes were beneficial for my learning (E).	18	16	3	2
Pre-lecture videos were technologically easy to use (T).	34	3	0	2
I watched pre-lecture videos prior to attending lectures (E).	33	3	0	3
The content of the pre-lecture videos was easy to follow (E).	36	0	1	2
The content of the pre-lecture videos helped me with practicing what was presented during lectures & workshops (E).	35	1	1	0
The content of the pre-lecture videos allowed me to discuss some mathematical questions with my peers, tutors, lecturer (S).	31	5	1	2
Overall, pre-lecture videos were beneficial for my learning (E).	36	1	0	2

In summary, the responses to the third research question "were students satisfied with the unit delivery?" are overwhelmingly positive. Students were satisfied with the ways the unit was delivered and, as a result, they perceived and took up technological, social and educational affordances of the "world of learning".

Finally, as mentioned above, the re-design of the unit also included out-of-class opportunities for learning provided by a university's learning support program ("STIMulate session"). The researchers made a conscious effort of embedding this module in the structure of the unit to the extent of making it "invisible", that is completely blending, non-compulsory, supportive and out-of-class activities with the remaining modules of the unit. There were multiple reasons behind the inclusion of the STIMulate sessions, the most important being providing students with as many opportunities of co-constructing knowledge as possible. Based on works by Vygotsky (1978) and his views on Zone of Proximal Development, the researchers believed that this particular module, if appropriately presented to learners as an opportunity of making learning progress, will successfully assist students with learning. Table 6 below summarises students' responses.

Table 6: Summary of questionnaire responses to research question 4 (N=39)

Question	Agree	Neutral	Disagree	No response
I was familiar with the STIMulate section on the unit BB site.	14	17	6	2
I knew where the STIMulate tutors were located.	24	12	1	2
I used STIMulate support for this unit.	13	14	10	2
STIMulate sessions were beneficial for my learning.	15	17	5	2

Based on the responses from students, the researchers conclude that this part of the re-design was the most challenging. Although made salient to students (most students did indicate knowing the location of the STIMulate tutors), it seems that the uptake of this affordance was not fully successful. Respondents' comments to this question might provide explanation why. Many students reported on not having the additional time to take advantage of this opportunity. For instance, one student wrote: " Unable to attend STIMulate due to work commitments", while another student stated: " Never went, had work on Wednesday". It seems that students 'frame of reference (student but at the same time, an employee), prevented students from taking up these educational and social affordances.

In summary, the researchers conclude that their ecological approach to learning, based on probabilistic learning design proved successful in promoting students' engagement with learning not only through unit content but also effective delivery fostering engagement.

Conclusion

Modern education is facing a challenge on unprecedented scale – how to prepare students to the requirements of the "learning economy", knowing that the world is only going to become more complex. Complex does not equal complicated. Gardner Campbell (2015), explained the important difference between complexity and complication. While complicated systems can be organised, planned, structured and controlled, complex systems escape such classification (and characterisation). Unpredictable, complex systems are at the forefront of the new order which, with time, could be theorised into a framework or a model.

The researchers undertook the task of addressing the complexity of technology-enhanced learning and teaching environments, by adopting an ecological perspective on learning resulting in creation of "world of learning". The results clearly shows that, overall, the adopted direction proved appropriate and beneficial to student learning. In response to four research questions, the researchers conclude that their attempt in creating a coherent and cohesive technology-enhanced learning and teaching environment was mostly successful. Students' perceived their academic achievement very positively as they engaged with learning through three modular pillars of the unit's environment: online, face-to-face delivery by teaching staff and collaborative co-construction of knowledge by support sessions. The results indicated the importance of a careful observation of the ever-changing environment, analysis of its constituents and reflection on the best ways of making opportunities for learning salient to all social agents. Such holistic understanding of the learning environment, seen as a learning ecosystem encompassing all constituents has the potential of assisting learners with the development of a very important skill – meaningfully engaging with learning.

References

Abeysekera L., & Dawson, P. (2015) Motivation and cognitive load in the flipped classroom: definition, rationale and a call for research. *Higher Education Research & Development*, 34(1), 1-14.

Biggs, J. & Tang, C. (2007). *Teaching for Quality Learning at University. Third Edition*. Open University Press.

Carbonell, K., et al. (2013). Unleashing the creative potential of faculty to create blended learning. *The Internet and Higher Education*, 18, 29-37.

Calderon, O., et al. (2012). Multidimensional assessment of pilot blended learning programs: Maximizing program effectiveness based on student and faculty feedback. *Journal of Asynchronous Learning Networks*, 16, pp. 23-37.

Campbell, G. (2015). *Education for uncertainty*. Key note given at HERDSA 2015 Conference: Learning for Life and Work in a Complex World, 6-9 July 2015, Melbourne, Vic.

Czaplinski, I. (2012). Affordances of ICTs: an environmental study of a French language unit offered at university level. Master of Philosophy thesis, University of Queensland. http://espace.library.uq.edu.au/view/UQ:289156

Czaplinski, I., Mallet, D., Burrage, P. & Psaltis, S. (2015). Preparing engineering graduates for the knowledge economy through blended delivery of mathematics. In HERDSA 2015 Conference: Learning for Life and Work in a Complex World, 6-9 July 2015, Melbourne, Vic. Retrieved July 10, 2015 from http://eprints.qut.edu.au/84517/

Entwistle, N. (1981). *Styles of Learning and Teaching: An Integrated Outline of Educational Psychology for Students, Teachers and Lecturers.* Chichester: Wiley.

Entwistle, N. (2000). Promoting deep learning through teaching and assessment: conceptual frameworks and educational contexts. TLRP Conference, Leicester, November 2000. Retrieved January 14, 2015, from http://www.tlrp.org/acadpub/Entwistle2000.pdf

Entwistle, N. (2009). *Teaching for Understanding at University. Deep Approaches and Distinctive Ways of Thinking.* Basingstoke: Palgrave Macmillan.

Estes, M.D., Ingram, R., & Liu, J.C. (2014). A review of flipped classroom research, practice, and technologies. *International HETL Review*, 4(6)

Fettes, M. (2003). Critical realism, ecological psychology, and imagined communities: foundations for a naturalist theory of language acquisition. In j. Leather, & J.van Dam (Eds.), *Ecology of Language Acquisition* (pp.31-47). Boston, MA: Kluwer Academic Publishers.

Gibson, J.J. (1977). The theory of affordances. In R.E. Shaw & J. Bransford (Eds.), *Perceiving, Acting and Knowing*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Gibson, J.J. (1979). *The ecological approach to visual perception.* Mahwah, NJ: Erlbaum.

Good, J.M.M. (2007). The affordances for social psychology of the ecological approach to social knowing. *Theory & Psychology*, 17(2), 256-295.
Goodyear, P. & Carvalho, L. (2013). The analysis of complex learning environments. In H.Beetham, & R. Sharpe, (Eds.). *Rethinking Pedagogy for a Digital Age*. Routledge, Second Edition.
Greeno, J.G. (1994). Gibson's Affordances. *Psychological Review*, 101(2), 336-342.
Hamdan, N., McKnight, P., McKnight, K. & Arfstrom, K. (2013). A review of flipped learning. Retrieved February 16, 2015, from http://www.flippedlearning.org/review
Herreid C.F. & Schiller, N.A. (2013). Case studies and the flipped classroom. *Journal of College Science Teaching*, 42(5), 62-66.
Hopkins, D. (2002). *A teacher's guide to classroom research.* (3rd ed.). Buckingham-Philadelphia: Open University Press.
Jamaludin, R. & Osman, Z. (2014). The use of a flipped classroom to enhance student engagement and promote active learning. *Journal of Education and Practice*, 5(2), pp. 124-131.
Jochems, W. M. G., van Merriënboer, J. J. G., & Koper R. (Eds.) (2004). *Integrated e-learning: implications for pedagogy, technology and organization*. London, England: Routledge Falmer.
Kirschner, P. (2002). Can we support CSCL? Educational, social and technological affordances for learning. In P. Kirschner (Ed.), *Three worlds of CSCL: Can we support CSCL*. Inaugural address, Open University of the Netherlands. Retrieved February 10, 2015, from https://www.ou.nl/documents/Promoties-en-oraties/Oraties/Oraties2002/oratieboek_PKI_DEF_Klein_ZO.pdf
Kirschner, P., Strijbos, J.-W., & Kreijns, K. (2004). Designing integrated collaborative e-learning. In Jochems, et al. (Eds.) (2004). *Integrated e-learning: implications for pedagogy, technology and organization*. London, England: Routledge Falmer.
Laurillard, D., Stratfold, M., Luckin, R., Plowman, L., & Taylor, J. (2000). Affordances for learning in a non-linear narrative medium. *Journal of Interactive Media in Education*, 2, 1-19.
Laurillard, D., Oliver, M., Wasson, B., & Hoppe, U. (2009). Implementing technology-enhanced learning. In N.Balacheff et al., (Eds.) *Technology-Enhanced Learning* (pp. 289-306). Springer Science + Business Media.
Marton, F., & Säljö, R. (1976). On qualitative differences in learning: 1. Outcome and process. British Journal of Educational Psychology, 46(1), 4-11.
McNiff, J. & Whitehead, J. (2002). *Action research: principles and practice*. (2nd ed.) SAGE.
Partridge, H., Ponting, D., & McCay, M. (2011). *Good practice report: blended learning*. Australian Learning and Teaching Council.
Powell, W.W., Snellman, K. (2004). The knowledge economy. *Annual Review of Sociology*. 30, 199-220.
Ramsden, P. (1992). *Learning to Teach in Higher Education*. London: Routledge.
Reed, E.S. (1996). *Encouraging the world: towards an ecological psychology*. New York :Oxford University Press.
Saliba, G., Rankine, L., Cortez, H. (2013). *Fundamentals of blended learning*. University of Western Sydney.
Siemens, G. (2015). *How we live and work is an important concern in our complex society*. Key note given at HERDSA 2015 Conference: Learning for Life and Work in a Complex World, 6-9 July 2015, Melbourne, Vic.
Stevenson, K. & Zweier, L. (2011). Creating a Learning Flow: A Hybrid course model for High-Failure Maths Classes. EDUCAUSE Quarterly, 34(4).
van Lier, L. (2000). From input to affordance: Social-interactive learning from an ecological perspective. In J. Lantolf (Ed.), *Sociocultural theory and second language learning* (pp. 245-60). Oxford, England: Oxford University Press.
van Lier, L. (2010). The ecology of language learning: practice to theory, theory to practice. *Procedia Social and Behavioral Sciences* 3, 2–6. DOI:10.1016/j.sbspro.2010.07.005. Retrieved July 10, 2015 from http://www.sciencedirect.com/science/article/pii/S1877042810013790
Vygotsky, L. S. (1978). Interaction between learning and development (M. Lopez-Morillas, Trans.).
In M. Cole, V. John-Steiner, S. Scribner, & E. Souberman (Eds.), Mind in society: The development of higher psychological processes (pp. 79-91). Cambridge, MA: Harvard University Press.
Willey, K & Gardner, A. (2013). Flipping your classroom without flipping out. *Proceedings of the 41st SEFI Conference*, 16-20 September 2013, Leuven, Belgium. Retrieved January 26, 2015 from http://www.academia.edu/5153284/Flipping_your_classroom_without_flipping_out