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Abstract:

This paper uses an adaptation of Brookfield's (2017) lenses to critically reflect upon a Subject Knowledge Enhancement Course designed and taught by the authors. Learning occurs through a synthesis of asynchronous engagement with online e-learning modules, weekly synchronous tutorials and self-reflection following formative and summative assessment opportunities. Interrogating the course design, learner feedback and observation, and tutor pedagogic choices through connectivist and social constructivist learning theory, the paper concludes that the common perceived learning gains occur through the flexibility in learning, and the supported autonomy that learners are given. Further developments in our offer should therefore aim to improve these opportunities for learners where possible.

Key Words:

SKE, e-learning, connectivism, reflection, flexibility, autonomy

Flexible autonomy: an online approach to developing mathematics subject knowledge for teachers

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This paper uses an adaptation of Brookfield's (2017) lenses to critically reflect upon a Subject Knowledge Enhancement Course designed and taught by the authors. Learning occurs through a synthesis of asynchronous engagement with online e-learning modules, weekly synchronous tutorials and self-reflection following formative and summative assessment opportunities. Interrogating the course design, learner feedback and observation, and tutor pedagogic choices through connectivist and social constructivist learning theory, the paper concludes that the common perceived learning gains occur through the flexibility in learning, and the supported autonomy that learners are given. Further developments in our offer should therefore aim to improve these opportunities for learners where possible.

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Introduction

Subject Knowledge Enhancement (SKE) programmes have successfully increased prospective teachers' confidence in the mathematics skills required for today's school curriculum – students surveyed have indicated a 53% increase in confidence from the start of study to the end of the course (80% expressed a high level of understanding) (Gibson, et al, 2013, p.33). The provision this paper is based on has seen a 99% student satisfaction rate regarding progression in mathematics subject knowledge, through online engagement with digital learning resources and virtual dialogues with a subject specialist tutor. We propose three reasons for this. Firstly, it is suggested that by harnessing knowledge forged via engagement with online learning materials, a 'More Knowledgeable Other' is able to increase understanding via interactive dialogues that contextualise learning within students' own personal experience and Zone of Proximal Development (Vygotsky, 1980). Secondly, it is suggested that the increasing accessibility of online learning resources changes the role of the tutor from that of the didactic pedagogue, to that of the provocateur who challenges and disrupts the understanding of the student in which to advance their knowledge (Osberg and Biesta, 2008). Thirdly, it is this combination of flexibility in learning with a sense of supported learner autonomy which threads through the different facets of the SKE course that leads to the development of learner knowledge and confidence.

Literature Review

There has been much speculation surrounding the notion that contemporary digital technology within teaching and learning transforms the nature of pedagogy in the 21st century. In recent years, it has been argued that established pedagogic models are increasingly obsolete as digital technology empowers students to direct their own learning. According to George Siemens (2004) and Stephen Downes (2012), online technology's capacity to facilitate networks of adaptable and accessible information empowers students to autonomously interpret data and make connections within their own learning. Learning in the digital age is therefore increasingly 'distributed across a network of connections, and therefore [...] consists of the ability to construct and traverse those networks' (Downes 2012, p. 85). These online networks are characterised by 'diversity, autonomy [and] openness' (ibid), allowing students the opportunity to independently and actively engage with a variety of information in a range of different modalities. From this viewpoint, greater emphasis is placed on students' ability to 'manage complex and rapidly changing [learning] environment[s]' (ibid, p.93). It is in this context, that Dorethy Kropf (2013) describes 21st century students as "do-it-yourself" learners who acquire information from a series of nodes and become active partners in learning. Here, nodes are to be understood as points within an online network at which a plurality of information both intersects and branches out. Accordingly, learning becomes 'an informal opportunity that transforms individuals into 'nodes' themselves, equally capable of sharing their knowledge and expertise with other individuals' (p.13). Siemens and Downes call this theory of online learning *Connectivism*.

For Green et al (2017), perceived benefits of online learning include flexible access, personalisation, agency and connectivity. Personalisation is the ability to provide 'unique learning pathways for individual students'; agency is the opportunity to allow students to 'participate in key decisions in their learning experience'; connectivity is the ability to give learners the opportunity to 'experience learning in collaboration with peers and [tutors both] locally and globally' (p.6). Online courses typically consist of a variety of multimodal interactive media to support learning. Kress (2010) defines multimodality as communication that incorporates several modes, understood as 'socially and culturally shaped resource[s] for making meaning. Image, writing, layout, speech, moving images are examples of different modes' (p. 79). Typical online multimodal media includes online forums, blogs, collaborative spaces, electronic documents, interactive online assessments, virtual spaces, digital videos and audio files. Mills (2011) suggests that an engagement with multimodal learning enhances students' experience, reception and comprehension – what is observed is a significant pedagogical shift, in which 'students are positioned to think [...] collaboratively and creatively within a community of practice' (p.2).

Digital online learning advocates the notion that online courses, such as SKE mathematics, provide an environment in which students can participate within a network of resources and dialogues that are amenable and responsive to their individual learning needs. Such a strategy therefore implies that online learning is not uniform and mechanistic, but a process in which needs and objectives are negotiated symbiotically, this is especially pertinent in the context of education where curriculums and performance outcomes are regularly transformed to coincide with wider ideological, cultural and economic changes in society.

How can an online strategy that forefronts notions of connectivity, diversity, autonomy and openness accord with the need to develop systematic knowledge and its application to set problems? Addressing such a problem includes considerations of teacher presence (the facilitator of learning), learner presence (the one initiated and motivated to learn), cognitive presence (understanding and its development) and social presence (collaboration and communication) (Shea and Bidjerano, 2010). All these considerations are also affected by notions of digital literacy. Utopian views of digital learning have been subject to criticism. Arguably, the diversity, autonomy and openness of data online is no substitute for an understanding of the application of knowledge within practicable real-life contexts. For example, a hospital patient would not be happy to see his or her doctor consulting his iPod for a diagnosis. Even though having the latest in research available is a requisite for the best medical treatment, it is no substitute for experience and personal knowledge from the doctor (Duke, et al, 2013). This lack of substantial connection to real-life contexts may diminish learning focus, accuracy and applicability. At the very least, it arguably reduces the potential awareness a prospective teacher might have applying mathematical concepts within the context of students' own experience and environments.

Within the realm of traditional learning theory, social constructivist strategies correspond the most with regards to the need to provide learners with a substantive experiential context for understanding. Social Constructivism posits the view that knowledge develops as a result of social interaction and is therefore a shared, rather than an individual, experience. According to Vygotsky (1980), students learn most effectively by interaction within a Zone of Proximal Development that allows students to scaffold their learning via communication with their peers and a More Knowledgeable Other within a social environment conducive to the context of their current understanding. Such a model provides opportunities for students to learn via a practical interaction that develops their understanding within a meaningful environment. Within the current context, the More Knowledgeable Other can be understood as the tutor able to provoke, challenge and contextualise students' understanding in which to give breadth and versatility to a prospective teacher's knowledge of mathematics, and can also be understood to include peers. This notion of tutor as provocateur is highlighted within Osberg and Biesta's (2008) concept of an emergentist pedagogy. According to this model, educational responsibility is about 'continuously complicating the scene, thereby making it possible for those being educated to continue to emerge as singular beings. Educational responsibility is about continuously re-opening subjectivity, unsettling closures, and unpicking 'destinations'' (p.326). By consistently challenging understanding via a range of contexts, questions and set problems, the tutor is able to move the learner beyond their comfort zone and enrich their learning.

It has been found that prospective teachers' attitude and knowledge of mathematics positively increased when subjected to a combined e-learning and problem-based approach that provides comprehensive knowledge, whilst challenging students to reflect upon, and evaluate their understanding (Uzel and Ozdemir 2012, p. 1157). Likewise, it has also been proposed that the most effective e-learning environments

are those that combine both autonomous, individual learning with a community of learning involving tutors and peers (Hung and Nichani 2000).

Arguably, the traditional role of the tutor as a conduit to knowledge is obsolete for students who can immediately access information online - this would increasingly be the case for higher education students who already have acquired skills for independent study. The role of the tutor as provocateur therefore seems more adequate for an activity that requires challenging and enhancing understanding. On the one hand, a hierarchical, didactic approach may lead to an unreflective model that lacks a deeper contextual understanding needed for the delivery of the subject to a differentiated range of students within a classroom. On the other hand, a connectivist approach, without active guidance from a tutor, risks a relativistic notion of knowledge that could lead to an erroneous or ineffective model of mathematic understanding lacking the context of real life practice. In this context, a combined connectivist and social constructivist model would seem to provide learners with the benefits of autonomy, whilst providing students with learning that is sensitive to the context of individual and practical experience.

Methodology

This paper adopts a critical reflection methodology; we attempt to uncover issues of power and hegemony (Brookfield, 2017) through using learning theory and observations and experiences of the SKE course to question or validate decisions made about the course structure and methods of learning. As our SKE course is relatively new and subject to continuous self-evaluation and revision, we choose to critically reflect using Brookfield's Four Lenses; theory, student eyes, colleague perceptions and personal experience (ibid).

The authors (a blended learning specialist, a mathematics education specialist and SKE course lead) design, teach and lead the SKE course inevitably drawing upon assumptions informed by our values, knowledge and practice about how we might best serve our learners. An effective and honest self-evaluation of this course must therefore 'unearth and scrutinise' these assumptions (ibid, p. 9), particularly related to the effectiveness of the tutor/student relationship (thus issues of power) and the balance of synchronous and asynchronous learning (and related hegemony). We use our review of blended learning literature, student feedback (written and oral), recordings of tutorial sessions, student e-portfolio data and individual tutor reflection to inform our analysis. This analysis will increase the effectiveness of the SKE course through providing a rationale for our choices and helping us take informed actions for continual improvement (ibid).

There is a lot of 'newness' and pedagogical uncertainty associated with this course. Subject Knowledge Enhancement courses have existed for a number of years, but there are currently no guidelines for the level of mathematical knowledge that applicants to courses have. Two students starting on the same day may have vastly different needs, with one being a recent engineering graduate on an eight-week course, the other having graduated in the social sciences many years ago and be undertaking a twenty-week course. The structure and material of the course is also subject to a process of continual review and editing. As such, although enrolment, progress, completion and attainment statistics are collected and monitored as part of

the improvement process, self-evaluation of the SKE course at this stage requires continual scrutiny of the course from a wide variety of vantage points. As such, our conclusions can only be secure for this specific course at this point in time, we will resist 'epistemological distortion' and claims of our findings remaining valid for further cohorts at different points in time (ibid). However, we attempt to look beyond the 'what, so what, now what' of reflection-in-action (Driscoll, 2007), and establish conclusions that, within the limitations of our research methods, are creditable, dependable and confirmable (Guba 1981, Shenton 2004).

Course Design

At Canterbury Christ Church University (CCCU), SKE mathematics courses start with an online induction, followed by an initial computer-based multiple-choice assessment. An individual action plan is then negotiated with a tutor via email to focus subsequent learning on individual's development needs. After this action plan has been instigated, students participate in weekly online tutorials and work through self-directed online resources accessed through the University's Virtual Learning Environment (VLE). This study then informs the production of online e-portfolios which evidence students' progression. At the end of the course, a final test measures a student's progression in mathematics. Success criteria for the course relate to engagement with the self-study materials, an increase in audit score, and a satisfactory e-portfolio submission. Course lengths range from eight to twenty weeks in duration, thus we tutor participants with mathematics degrees who require a refresher, and those without mathematics A-level within the same cohort. Applicants are pre-trainees on university-led or employment-led ITE courses, training to teach age ranges 7-14, 11-16, 11-18 or 14-19 and have a range of previous experiences of online learning.

Flexibility and supported autonomy are embedded within the course design and are explicit in the CCCU SKE mathematics programme's aims:

- refresh, consolidate and improve subject knowledge in relation to the primary and secondary national curriculum;
- develop mathematical thinking; develop an awareness of mathematics in real-life contexts;
- promote independent learning, improve meta-cognitive skills and develop students' ability to identify and address their own learning needs.

The course allows students to flexibly engage with learning at a pace, time and location that corresponds and is convenient to their wider professional commitments and priorities. The online mathematics resources are structured according to topics that correspond to the needs and requirements of the mathematics national curriculum and are modelled on how children learn mathematics in the classroom. In order to promote autonomy, each unit (approximately 8 hours' work) can be studied in sequence or standalone, giving students the ultimate flexibility in creating their own path in response to their initial mathematics skills audit. As noted above, following an initial audit, students undertake a gap analysis and, in discussion with their tutor, design their own pathway through the resources.

As well as having a wide range of on demand sessions to select from in order to design their own pathway (there are more than 50 sessions available), the sessions themselves were designed by an experienced team of mathematics educators following a social-constructivist model of learning mathematics. For example, in the session entitled “From Paper Folding to Angle”, students explore and develop their understanding of angle rules through investigating the properties of A4 paper.

It is relatively easy to ensure that on-demand materials provide flexibility and autonomy. Doing so for live tutorials is more problematic, and a number of models have been explored in order to meet this need. A common model is negotiating the programme with the tutor during the induction tutorial. This ensures that topics identified by students are addressed, but, it is impossible to meet the needs of a cohort of up to 30 students who enter the programme from vastly different levels and types of engagement with the subject. Similarly, a workshop model where a specific focused problem is introduced has been trialled, but was found to only meet the needs of a minority. The current delivery model aims to mitigate both of these challenges and is modelled as follows:

- KS3 and GCSE up to grade 4 (20 week rolling cycle)
- KS3 and foundation GCSE (16 week rolling cycle)
- GCSE mathematics (12 week rolling cycle)
- Higher GCSE and introduction to A-Level (8 week rolling cycle)

On the first Saturday of every month (from January to July) a new cohort starts.

Students are advised to enrol on different length courses according to the area of the mathematics curriculum they need to develop, which roughly correspond to the areas given above. There are four tutorials a week, one for each of the rolling cycles. The rolling cycles are designed so that a student can join in at any stage, thus the students at each live tutorial will be at different stages of the course. Students do not have to commit to any one of the four rolling cycles - they are free to swap from week to week, or attend more than one tutorial a week. For example, an engineering graduate may choose to skip the mechanics session, but attend the foundation GCSE proof tutorial earlier the same evening.

The course design therefore offers a combination of flexible learning, through both access to and the pedagogical design of on demand resources, and supported learner autonomy, through the structuring of live tutorials, which lead to both the development of mathematical knowledge and understanding and the confidence of learners..

Analysis

Our analysis considers how the CCCU SKE mathematics course provides both flexibility and supported autonomy using Brookfield’s four lenses as its framework (Brookfield 2017). Firstly, by considering student learning, we critically reflect upon the lens of student eyes and personal experience in which to ascertain the perceived learning benefits and limitations of SKE mathematics provision from the viewpoint of the learner. Secondly, by considering tutor pedagogy, we reflect upon the lens of

colleague (tutor) perceptions and theory to highlight the benefits and limitations of the course from the viewpoint of teaching strategies.

Student Learning

The current course design is intended to allow students to enhance their understanding through flexible engagement at a pace, time and location that corresponds and is convenient to their wider professional commitments and priorities. The format of these courses is deemed appropriate because online learning is typically not limited by geographical and temporal restraints – it is often virtual, asynchronous and non-proximal. In this subsection, we consider the on-demand sessions and live tutorials through the lens of the student and their personal experience, considering three main areas: how students manage the design of their own pathway through the on-demand materials, how students perceive the social-constructivist nature of the on-demand materials, and how they use the live tutorials.

Many students are initially overwhelmed by the quantity of on-demand materials available to them. One adaptation that has been made to the course design in response to this is to provide direction towards sessions which will address the needs identified within the audit. In their feedback students will be told, for example, that if they got question 22 wrong, in which they had to solve a system of simultaneous equations, then they should use the on demand session 16.2, solving simultaneous equations. Students are also provided with a gap analysis in the form of a spreadsheet in which they RAG-rate their confidence against each session title, and use this to prioritise sessions. Some students use this to make a strategic plan, others report that it feels like empty bureaucracy and take a more ad hoc approach to selecting sessions. There is some evidence that a strategic pathway based on audit feedback and gap analysis leads to better outcomes as the following three examples of students on the 2-week programme from a 2018 cohort illustrate:

	Pathway through on demand sessions	Initial audit result	Final audit result	Overall grade
Student 1	15, 1, 2, 3, 4	52	61	Satisfactory
Student 2	1, 2, 3, 4, 5, 8, 15, 11, 12, 6, 16, 17, 20, 23, 19, 21, 25, 26, 31, 33, 34, 36, 24, 43, 44, 46, 51, 58, 57, 56, 55, 54, 53, 52, 50, 49, 59, 70, 41, 42, 29, 18, 14, 13, 7, 6, 17, 16, 23, 46, 38, 37, 45, 47, 48	32	49	Good
Student 3	2, 4, 6, 7, 8, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 29, 36, 1, 3, 5, 9, 24, 25, 28	41	101	Excellent

Many students find the investigative nature of the on-demand sessions to be problematic. The social-constructivist principles which informed the design of these

sessions work well in a classroom where learners can interact with their peers and more knowledgeable others. The second and third stated aims of the SKE programme are to develop mathematical thinking, and to place mathematical knowledge within meaningful contexts, and so it is vital that students perceive mathematics as a discursive, social discipline, but this can be hard to achieve when learners are isolated both geographically and in time. Attempts to address this have included the provision of solutions (which include notes on methods and alternative approaches) and the availability of the tutor to discuss sessions via email. Additionally, tutors are sensitive to this in the planning and delivery of live tutorials, when the essential discursive nature of mathematics and its learning can be addressed.

In their final reflections, many students comment on how the live tutorials were the most useful part of the course to them, for example:

“The weekly tutorials **by** were very informative and highlighted areas that I needed to revise further, this for me was the most practical part of the course.”

“The questions we solved ... were pivotal for learning progression.”

“ I found the online live lessons to be helpful and has given me some confidence in what I am doing.”

The model of rolling cycles differentiated at four levels across four separate tutorials each week was intended to enable students to select the live tutorial most appropriate to them. Many students attended all four tutorials every week, which meant that they encountered the same materials up to four times, but delivered at different speeds. Students explained that they were happy to be overwhelmed by the materials in early sessions, knowing that they would revisit it and grow in confidence. One said that the first time round she felt like an outsider observing others doing the maths, the next time she was a consumer of the mathematics, before finally moving into the roles of expert and leader. As the tutorials were on a rolling programme with new students joining every four weeks, this created a supportive learning environment in which not only the tutor was able to act as provocateur and more knowledgeable other, but students were able to do so too.

Issues of poor student engagement due to lack of confidence in an unfamiliar learning environment is reduced as new cohorts join groups who have already established learning habits and the new social norms of the online classroom.

Tutor pedagogy

From the perspective of a theoretical lens, students' access to a range of online maths materials and resources follows the principles of connectivism by providing a diverse and open space in which to autonomously develop their understanding. Given that students have both the flexibility and autonomy to develop their own understanding via engagement with these materials, the responsibility of the tutor becomes less about knowledge transference and more about provocation - the role of provocateur allows the tutor to challenge and problematise students' subject knowledge in which

to think more deeply about their understanding which, in turn, induces a more adaptable and contextual approach to the knowledge they have acquired. Through the lens of the tutor, the benefits of combining a problem-based approach to students digitally informed understanding is apparent. Tutor and student interaction during tutorials provided opportunities to both challenge students' understanding and provide contextual and individual guidance to enhance understanding of mathematics topics.

Tutors were able to act as a provocateur in the on demand sessions. For example, in the session described above, students were guided through the steps to fold a sheet of A4 paper to create equilateral triangles and then use these to construct tetrahedra and octahedra, but were then later challenged to use this activity to prove the ratio of the lengths of the sides of the paper. In an introduction to calculus, students are supported in understanding both the fundamentals and applications of differentiation through film clips of a car chase.

Online tutorials typically begin with a series of challenges to problematize students' understanding of topics studied via engagement with online resources. The provision of mathematical problems allows both the student and tutor to confirm the current level of understanding and identify potential gaps or issues that can then be addressed. After potential gaps in understanding have been identified, the tutor is then able to recognise errors and provide guidance that is bespoke to student's individual context and experience – it is in this sense that, from a social constructivist point of view, both tutor and peers can act as More Knowledgeable Others who can challenge and question students within the context of their own understanding. In one particular tutorial that was videoed for self and peer observation purpose, students were invited to use their existing knowledge to suggest which mathematical object best exemplifies key mathematical terminology, such as “expression” or “inequality”. Drawing mainly on their knowledge of the English language, students suggest pairings and are prompted by the tutor to explain their thinking. The tutor is particularly interested to hear the thinking behind incorrect pairings. As this example demonstrates, by identifying the symptom of errors and the reasoning behind them, the tutor is able to provide a solution and explanation that connects with the student's own context. From the lens of tutor, it would therefore appear that students' confidence and understanding of mathematics is increased by combining independently accessed online resources with challenging and contextual tutor interaction.

Conclusion

Our reflections through the lens of theory, tutor and student has found that by combining online learning materials with the support of a 'More Knowledgeable Other', students are able to effectively increase their understanding of mathematical concepts – this is achieved via interactive dialogues that both challenge and contextualise learning developed online. This takes into account students' Zone of Proximal Development (Vygotsky, 1980) and forges further development through the guidance of the tutor as More Knowledgeable Other. Such reflections therefore suggest that the increasing accessibility of online learning resources changes the role of the tutor from that of didactic pedagogue, to that of the provocateur who challenges the understanding of the student in which to advance their knowledge (Osberg and Biesta, 2008). Finally, these reflections highlight that a combination of flexibility in learning with supported learner autonomy leads to both the development of learners'

understanding and confidence. This combination highlights the importance of differentiation as a key issue in presenting and delivering materials. Students begin the SKE course by taking a diagnostic test in their own time and use this to autonomously develop an individualised learning programme. Students then have a vast range of asynchronous online sessions to select from, which may initially be informed by their initial action plan but can then be altered as their learning journeys take place as the course unfolds. These differentiated asynchronous course resources have been found to promote independent active engagement by participants in their mathematics, evidenced by their asking their own questions and constructing their own understanding of the content.

While autonomous online learning lead to an effective comprehension of relevant mathematical knowledge, it lacks the opportunity to enrich, adapt and negotiate understanding within the context of challenging and practical applications. By providing opportunities for social interaction during online tutorials, our reflections suggest that students can enhance and extend their knowledge through a variety of challenging problems and questions, many of which place a greater emphasis on processes and algorithms to complement their developing conceptual understanding. The multiple needs of the learners and the large choice in course length currently means that an 'ideal' tutorial structure is difficult to achieve; several models have been used in order to tailor the real-time tutorials to the individual needs of students. Our current 'rolling structure' model has proved most able to fulfil the very different needs of students whilst maintaining the flexibility and autonomy identified as being so important to online learners.

Whereas digital learning, epitomised in the theory of connectivism, allows students to flexibly engage with learning at a pace, time and location suitable to their individual needs, a reflection on the experiences of students and tutors concludes that students' deeper and enhanced understanding of mathematics benefits from the complementary use of a social-constructivist model of learning.

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