ABSTRACT

BACKGROUND: The emergence of the internet, particularly Web 2.0 has provided access to the views and opinions of a wide range of individuals opening up opportunities for new forms of communication and knowledge formation. Previous ways of navigating and filtering available information are likely to prove ineffective in these new contexts. Connectivism is one of the most prominent of the network learning theories which have been developed for e-learning environments. It is beginning to be recognised by medical educators. This paper aims to examine connectivism and its potential application.

CONTENT: The conceptual framework and application of connectivism are presented along with an outline of the main criticisms. Its' potential application in medical education is then considered,

CONCLUSIONS: While connectivism provides a useful lens through which teaching and learning using digital technologies can be better understood and managed, further development and testing is required. There is unlikely to be a single theory that will explain learning in technological enabled networks. Educators have an important role to play in online network learning.

(Word count 170)

Connectivism: a knowledge learning theory for the digital age?

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INTRODUCTION

Modern society, with its rapid scientific and technological advances, has seen an exponential rise in accessible knowledge and continuously changing and emerging technologies. The emergence of the internet, particularly Web 2.0, has provided access to the views and opinions of a wide range of individuals opening up opportunities for new forms of communication and knowledge formation inside and outside of formal educational institutions. Previous ways of navigating and filtering available information are likely to prove ineffective in these new contexts. The ability to access relevant information and harness the resources offered by the views and opinions of others have become important skills particularly as the need for lifelong learning, both formal and informal is increasingly recognised by individuals, organisations and institutions (Cheston et al., 2013, Flynn et al., 2015).

Educators adapting to new learning environments may turn to learning theories to guide them. If existing theories no longer fully or only partially explain learning in these contexts new theories need to be developed. These may build on existing theories without discarding them or totally replace existing theories. Connectivism is one of the most prominent of the network learning theories that have been developed for e-learning environments. It first appeared in Siemen's (2005) on-line publication "Connectivism: A learning theory for the digital age", ideas which have been developed by Downes (2005, 2006. 2012). It is beginning to be recognised by medical educators (Sandars and Morrison, 2007, Sandars and Haythornthwaite, 2007, Mehta et al., 2013, Lau, 2014, Downes, 2015, Flynn et al., 2015) due to its' claim to provide a lens through which teaching and learning using digital technologies can be better understood and managed. This paper aims to examine connectivism and its potential application in medical education.

CONNECTIVISM

Connectivism is a conceptual framework which views learning as a network phenomenon influenced by technology and socialization (Siemens, 2006). It is claimed to have roots in principles explored by chaos, network and complexity and self-organisation theories (Siemens, 2005). Downes (2012) asserts it is also supported by connectionism, associationism and graph theory.

Its epistemological framework, based on the concept of distributive knowledge (Downes, 2006), is considered distinct from the epistemological traditions (Driscoll, 2000) of objectivism, pragmatism and interpretivism. Siemens (2005) considers these existing traditions limited due to their intrapersonal view of learning, their failure to address the learning that is located within technology and organizations and their lack of contribution to the value judgments that need to be made in knowledge-rich environments.

The principles of connectivism, after Siemens (2005) are:

- Learning and knowledge rest in diversity of opinion
- Learning is a process of connecting specialised nodes or information sources.
- Learning may reside in non-human appliances
- Capacity to know is more critical than what is currently known
- Nurturing and maintaining connections is needed to facilitate continual learning
- Ability to see connections between fields, ideas, and concepts is a core skill.
- Accurate, up-to-date knowledge (currency) is the aim of all connectivist learning activities.
- Decision-making is a learning process in itself.

In connectivism the starting point for learning occurs when knowledge is actuated by learners connecting to and participating in a learning community. Learning communities are defined as "the clustering of similar areas of interest that allows for interaction, sharing, dialoguing and thinking together" (Siemens, 2005). Participation results in conversations between learners and other members of the community including more knowledgeable others. These conversations in the web 2.0 era consist not only of words but also of images e.g. video, multimedia etc. With the advent of web 2.0 learners are able to create personal learning environments (PLEs) (Milligan, 2006), which allow for the production as well as consumption of learning resources.

In the connectivist model the learning community is described as a node, which is always part of a larger network. Nodes emerge from the connection points found on a network. Nodes may also be organisations, libraries, web sites, journals, databases or any other sources of information (Siemens, 2006). Networks comprise two or more nodes which are linked in order to share resources. They may be of varying size and strength depending on the concentration of information and the number of individuals navigating through a particular node (Downes, 2007). Successful networks are considered to have the following characteristics (Downes, 2006, 2012):

- Diversity - the widest possible spectrum of points of view
- Autonomy of participants
- Openness – mechanisms which allow perspectives to be entered into the system
- Connectivity – connections between its nodes

The networks learners connect to can be small and local or vast and global. During learning they may traverse multiple knowledge domains as the peripheries of knowledge fields are porous. Learners therefore have potential access to rich tapestries of resources, dynamic and interconnected, created not only by knowledgeable others but by all members of the community and by technology (Downes, 2006). There are parallels with Ilich's (1971) utopia where educational systems in societies are constructed as a network of relations through which learners can access the resources they need at any time. However, his idea of "community webs" was more local, situated in community settings and aimed at bringing learners together with local people and "people with knowledge".

Connectivism asserts that knowledge and learning knowledge are distributive i.e. they are not located in any given place, but instead consists of networks of connections formed from experience and interactions between individuals, societies, organisations and the technologies that link them. Knowledge is viewed as a process, fluid and dynamic flowing through networks of humans and their artefacts. As it flows through and becomes part of the network it is open to multiple interpretations and change. Knowledge resides within networks, without any individual necessarily possessing it, and it can be stored in a variety of digital formats.

Connectivism is an emergent theory of the mind. Patterns of input phenomenon cause or create patterns of connections which are distributed in neural networks in the brain. These connections are formed naturally during interaction and are associative i.e. they form when two neurons are active at the same time and weaken when they are inactive or active at different times. Knowledge is viewed as interconnected, the same neurons can be involved through non-symbolic interconnections in disparate concepts such as "platelets are red blood cells" and "Edinburgh is the capital of Scotland". While cognitive theory views knowledge as schema or symbolic mental constructions, and learning as a change in learners' schemas, connectivism views knowledge as sub-symbolic with meaning arising from interaction of sets of connections rather than single symbolic units (Downes, 2006, 2012). Knowledge may consist in part of linguistic structures, but it is not essentially based in them or subject to their constraints. Downes (2012, p87) proposes "there are no mental models per se (i.e. no systematically constructed rule-based representational systems) and

what there is (i.e. constructivist networks) is not built (like a model), but grown (like a plant)." Representational means are seen as epiphenomena of knowledge. The substance of knowledge is considered to be the recognition and interpretation of patterns of connections that arise. Knowledge is viewed as personal as individuals may interpret the same concept differently. It is context sensitive not a stand-alone symbolic representation, but comprehensible only within the rich set of world views, previous experiences and frames in which it is embedded. As the available knowledge becomes increasingly complex it is the patterns of connections rather than the individual elements that become most important in gaining understanding. "It is recognition of a pattern in a set of neural events (if introspecting) or behavioural events (if observing). We infer to mental contents the same way we watch Donald Duck on TV – we think we see something, but that something is not actually there – it's just an organization of pixels" (Downes, 2006, p3).

Learning occurs through the construction and traversing of networks. Participation in network activities results in the creation, removal or adjustment in strength of connections. It is recognition of the salience of patterns by perceivers in the network which constitutes learning. These connections emerge collectively outside the brain through interaction and within the brains of individuals. Connectivism proposes that learning may also reside in "non-human appliances" where it may be stored and manipulated by technology (Siemens, 2006). In connectivism there is no real concept of transferring knowledge, making knowledge, or building knowledge. Instead it emerges from the connections that are formed during network activity. Distributing cognition, sense and meaning making and filtering to networks of human and technological nodes helps cope with the rapid expansion of available knowledge (Siemens, 2006). Downes (2006) explains the emergence of knowledge as the conjunction of four elements:

- Context - the localization of information sources in a network
- Salience - the recurrence of a pattern in the network. If a signal creates activation of a set of connections that were previously activated, it is considered salient.
- Emergence - the development of patterns in the network. When a pattern is salient to a perceiver it emerges in the network
- Memory - the persistence of patterns of connectivity that result from, and in salient signals or perceptions

Since information is constantly changing, its relevance will be affected by new contributions made to the field. Learners need to be able to access new information, evaluate its' relevance and make decisions on the basis of the information acquired. The ability to seek out current information and filter secondary and extraneous information are considered important skills that contribute to learning. The learning process is cyclical, learners connect to a network to find and share new information, modify their beliefs in terms of their new learning then reconnect to share their new understandings and find further information.

APPLICATION OF CONNECTIVISM

The main pedagogical method has taken the form of massive open online courses (MOOCs). These were conceptualised by Siemens and Downes (2008, 2009) as huge networks of connected people and resources that learners can access and use to design and direct their learning. They ran the first one in 2008 on "Connectivism and Connected Knowledge" attracting over 2000 worldwide participants. Educators had the role of facilitator or were totally absent from the learning process. All course content was available through RSS feeds, and learners could participate with their choice of tools: threaded discussions in Moodle, blog posts, Second Life and synchronous online meetings.

Learners use digital platforms such as blogs, wikis, and social media platforms to make connections with content, learning communities and other learners to create and construct knowledge. They are encouraged to contribute actively, using these digital platforms. Participants' contributions in form of blog posts, tweets etc. are aggregated by course organizers and shared with all participants via daily email or newsletter.

The concept of massive open line online courses has been adopted by leading campus-based universities. Thurn and Norvig from Stanford offered an online course called "Introduction to Artificial Intelligence" in which over 160,000 students from more than 190 countries enrolled. Coursera, founded in 2012 by two Stanford University lecturers, had 1.5 million students from 190 countries enrolled in 198 MOOCs provided by 33 universities by 2013. MOOCs are also receiving considerable attention in Europe. The European Commission (2013) advocated opening up education through the use of MOOCs. This was followed by the launch of Openup Ed (http://www.openuped.eu/) by a group of European Universities to help achieve this aim. By 2014 over 600 MOOCs were available in European institutions (Steffans, 2015).

These MOOCs are offered on university based platforms and most often modelled on traditional course materials, learning theories and teaching methods. They are usually organized around pre-recorded video lectures, which are posted on the platform, although interactive elements including quizzes and discussion forums are often included. Traditional assessment methods such as computer marked MCQs are mainly utilised. Most MOOCs are not "open" as they are only available to those who have signed up (and in most commercial MOOCs paid) for the course. Downes has coined the terms cMOOC and xMOOC to differentiate the two types. The "c" in cMOOC represents the connectivist nature of the MOOC, whereas the xMOOCs are seen as extensions of university courses.

CRITICISM OF CONNECTIVISM

As with all new theories connectivism has been the subject of criticism. Not only has its' claim to be a new theory, distinct from traditional epistemological paradigms been questioned, but also its' status as a learning theory per se. However, what constitutes educational theory and its' relationship with practice is contested (Thomas, 1997, Carr, 2006). A detailed examination of the philosophical and epistemological issues is beyond the scope of this paper and it will therefore concentrate on outlining the main areas of criticism.

Connectivism's claim to be a new theory for network learning has been questioned as many of its' underlying principles can be drawn from theories from the traditional epistemological paradigms, particularly constructivist theories, which are still considered fit for purpose (Verhagen 2006, Foster, 2007, Kerr, 2007, Kop and Hill, 2008, Bell, 2011, Boitschwarelo, 2011, Ravenscroft 2011, Lange 2012, Clara and Barbera, 2013). For example, Vygotsky's (1987) formulation of social constructivism, Engestrom's (1987) Activity theory, Bandura's (1986) social cognitive theory, Lave and Wenger's (2002) Situated Learning theory, Papert's theory of constructivism (Papert and Idit, 1991) and Clark's (1997) theory of embodied action cognition all emphasise the social, situational and relational aspects of knowledge and learning. Vygotsky and Clark previously highlighted the distributed nature of knowledge, while Engestrom extensively examined the role of mediating artefacts in learning. Philosophical criticisms that have led to its' status as a learning theory being questioned include the perceived lack of connection between connectivism's underlying principles and the arguments and theories on which it is based (Verhagen, 2006, Barry, 2013, Clara and Barbera, 2013) The lack of explanation for the assertion that learning may reside in non-human appliances is a major criticism. Despite advances in fields such as machine learning this has proved a highly contentious concept. One can conjecture it is the pattern recognition abilities of machines which allows them to make connections that can be used by humans. However, it has not been clearly explained by Siemens.

Similarly lacking is an explanation of how subjects access such knowledge. In addition, an under conceptualisation of the role of the other in the network and an oversimplification of the evolution of interaction in network learning has been discerned (Clara and Barbera, 2013). Connectivism's explanations of knowing also appear to focus on the individual, which was one of Siemens major criticisms of existing theories from traditional epistemological paradigms (Clara and Barbera, 2013).

The lack of empirical testing has also been criticised (Bell. 2011). Studies which have taken place have been mainly in the context of MOOCs and the results mixed. Kartensi's (2013) literature review reported low success rates among participants. Armstrong (2013) similarly found a high drop-out rate. Mackness, Mak, and Williams (2010) found that when the theory of connectivism is situated even in the practice of a cMOOC its network principles of diversity, autonomy, openness, and emergent knowledge may be compromised. Other studies, however, found MOOCs have the potential to foster student autonomy and create learning communities (Kartensi, 2013).
Garcia et al.'s (2015) case study on the use of collective student blogs similarly found autonomy was fostered, participation promoted and connections created although it was not universal among students. Hogg and Lomicky (2012) study of students' on-line course experience similarly found that while autonomy and openness were present, interaction was less evident and diversity was lacking. Participation and autonomy has been found to be promoted by the "social presence" of facilitators and other participants, which fostered a sense of belonging and community that built confidence and stimulated active participation (Kop, 2011, Hogg and Lomicky, 2012, Garcia et al., 2015).

Despite its' limitations most authors recognise connectivism's potential to provide a useful perspective as to how learning might occur in the digitally saturated, connected world we live in (Verhagen 2006, Foster, 2007, Kerr, 2007, Kop and Hill, 2008, Bell, 2011, Lange 2012, Clara and Barbera, 2013). Verhagen (2006), for example, views its' relevance at the curricular level contributing to new pedagogies in environments where control is shifting from the tutor to more autonomous learners. While further development and testing is recommended connectivism is increasingly being described as a theory in the educational literature. For example, it has been included in the list of learning theories at http://www. learningtheories.com where it is classified within the constructivist paradigm. Flynn et al.'s (2015) study of Canadian medical educators reported unanimous consensus that connectivism was a particularly relevant learning theory informing the use of social media in medical education. Other learning theories, particularly from the constructivist paradigm were also considered relevant and it is unlikely that educators will only draw on connectivism to help understand learning in technological enabled networks.

POTENTIAL APPLICATION IN MEDICAL EDUCATION

Medical teachers have the potential to enhance learning by integrating technology into medical curricula in innovative ways guided by relevant theory. Connectivism can inform medical educators at classroom level. Teachers interested in embracing connectivism in their day to day practice may wish to consider the following suggestions (after Bell, 2009):

- Follow the blogs of those who innovate with educational technologies
- Experiment (within your comfort zone) with web services and tools that might enrich teaching and learning in your practice.
- Encourage students to use the web for scholarly resources – being critical and selective, and attributing sources. Teachers can offer scaffolding and support and provide opportunities for reflection.
- Use, publish and share resources through blogs, wikis, photo and video sharing sites. This can help in the creation of flexible leaning environments that incorporate authentic context,

for example using problem and case-based material to build collective resources and share best practice.

- Assign student activities that enable effective use of media to report process and, where appropriate, outcomes.
- Creating online communities using social media promotes connectivity. Studies have shown using social media in medical education promotes learner engagement, feedback and collaboration, and the development of professionalism (Cheston et al., 2013, Hollinderbaumer et al., 2013). However, it is not without its' challenges. Cheston et al.'s (2013) review found both students and teachers experienced technical problems with social media platforms, variable learner participation and issues with privacy, professionalism and patient confidentiality particularly if on unsecured networks.
- When establishing online learning communities, it is useful to look at recognized models, for example the ParkinsonNet programme from the Netherlands (Nijkrake et al., 2010), which was established to promote the provision multidisciplinary care for patients with Parkinson's disease.

MOOCs have the potential to promote network learning using technological enabled networks at curricular level. Mehta et al. (2013) envisage the development of a central online collaborative learning environment instead of multiple medical schools teaching the same content at multiple sites. Resources could be pooled to develop MOOCs covering, for example basic medical sciences which could be implemented across all UK medical schools via secure virtual learning environments (VLEs) such as MOODLE. This could prove cost-effective (Armstrong, 2012, Daniel, 2012). To run MOOCS as conceived by Siemens and Downes would not be possible in the context of undergraduate medical education as learning needs to be more structured and they could not be truly "open". Nevertheless, their development should be guided by connectivism and other relevant theories. For example, Downes (2012) advises for effective learning the content should be:

- Interactive - involving learners who share the same area(s) of interest.
- Usable - users need to be able to navigate through complex and rich information.
- Relevant - this is promoted by precision and simplicity e.g. placing each lesson on its own page, making sure the page contains words and phrases that would lead a searcher to its content and placing it in a logically designed directory of related content ensure that learners find exactly what is needed. This requires effective search engines.

Multidisciplinary collaboration could be promoted by building communities of practice that include other health care professionals such as nursing, pharmacy or physiotherapy students. More experienced peers could refer back to these courses while in clinical rotations and, in addition to content experts, also act as "knowledgeable others". This would also help promote network diversity. Similarly, MOOCs could be developed covering more complex problem-solving and clinical reasoning areas where postgraduates could participate in similar ways. Communities of practice formed early in medical school could provide a foundation for lifelong learning. The number of students involved in these MOOCs would ensure that there would always be other participants online helping to build a virtual, multidisciplinary, collaborative environment. Access to content would be 24 hours per day, seven days per week allowing for flexibility of learning. The role of teachers in individual medical schools would become more of facilitator being available for face-to-face, on-line small group, or on-line one-on-one discussion. Teacher participation would be more intensive at the beginning reducing as learners engage. As mentioned previously the "social presence" of facilitators in networks promotes student participation and autonomy.

The connectivist view of curriculum as process and knowledge gain developmental is likely to lead to criticism due to perceived lack of clear direction, loss of teacher control and difficulty with

assessment. Direction is provided by having clearly stated learning outcomes. Teachers have a pivotal role in the process although as students become increasingly autonomous their role would be more facilitative. In the connectivist approach learning would be assessed not only in terms of individual knowledge gain, but also through evaluation of the learning process. For example, the ways learners connect with others to collaborate and share the creation of knowledge and also the production as well as consumption of learning resources by students. The amount of data generated by the online networks provides opportunities for such evaluation. Learning analytics, the analysis and representation of data about learners in order to improve learning, is a new lens through which educators can understand learning and provide feedback for students. It is rooted in the dramatic increase in the quantity of data about learners, and linked to management approaches that focus on quantitative metrics (Clow, 2013). Starkey (2011), for example has promoted the use of such a digital learning matrix to assess learners. Accreditation is important as it provides extrinsic motivation promoting participation (Bouchard, 2009). It may take some time to convince medical schools and accreditation bodies of the value of such assessments.

CONCLUSIONS

- While connectivism provides a useful lens through which teaching and learning using digital technologies can be better understood and managed further development and testing is required.
- There is unlikely to be a single theory that will explain learning in technological enabled networks.
- Educators have an important role to play in online network learning.

(Word count 3748)

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John Goldie was lead researcher in the evaluation of ethics learning in Glasgow University's curriculum. He is currently lead researcher on projects investigating the delivery of professionalism teaching and the formation of medical students' professional identity. He has been involved in postgraduate education and continuing professional development for many years.

PRACTICE POINTS

- There is unlikely to be a single theory that will explain learning in technological enabled networks.
- While connectivism provides useful pedagogical principles it requires further development and testing.
- Educators still have an important role to play in online network learning

I have no conflicting interests

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