Physics students' social media learning behaviours and connectedness

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Introduction

Social media connectivity does not necessarily lead to connectedness. The OECD (2012) report on the New Millennium Learners project makes a distinction between *connectivity* and *connectedness*, where connectedness is defined as the ability to *benefit* from being connected. Depending on the context, connectedness with social media may mean being able to leverage professional connections to find and be hired for a new job (e.g., LinkedIn), learn something new from blog postings shared on Twitter, or build a new network of friends who share a similar set of interests by joining a Facebook group. The current study is about the ways in which students may or may not demonstrate connectedness in their learning context; specifically physics learning contexts. The extent to which today's youth participate in activities that connect them to each other and to information (i.e., connectivity) is vividly apparent, but little is known about students' abilities to utilize the potential of their connections to facilitate learning (i.e., connectedness). To consider how educators might help foster the shift from connectivity to connectedness using social media, we examined students' social media learning behaviours – ways that students use social media to support their academic learning. We used a complexity thinking perspective on learning (Davis & Sumara, 2006) in order to characterize how social media learning behaviours might lead to connectedness. Finally, we were interested in how social media learning behaviours evolved over the learning spectrum and within a particular disciplinary context. Our work aims to obtain broad insight into the issue of connectedness, an intrinsically important part of optimizing the potential for enhancing learning using social media tools. Thus, in this study we asked the following research questions:

1) What social media learning behaviours do secondary and tertiary science students engage in, and how do these differ across the groups?
2) How can social media learning behaviours be characterized using complexity thinking and what are their potentials for connectedness?

For the purposes of our study, social media are defined as software and web-based technologies that facilitate interactive dialogues and connectivity using the capabilities of Web 2.0 technology that allow for the creation and exchange of user-generated content (Kaplan & Haenlein, 2010). Examples include video sharing platforms (e.g., YouTube), image sharing sites (e.g., Flickr), and social networking sites (e.g., Facebook, Twitter).

Today's Connected Learners

The first generation to grow up surrounded by digital media has reached a metaphorical age of graduation. They have been characterized as 'digital natives' (Prensky, 2001a), 'New Millennium Learners' (OECD, 2010, 2012), and the 'Net Generation' (Oblinger & Oblinger, 2005), and their skill set and preferences for all things digital are taken for granted as a generational phenomenon. A number of claims have been made about this generation of learners: they prefer active learning to passive learning (Oblinger & Oblinger, 2005); they want to receive information quickly (Prensky, 2001a); and they are skilled at so-called multi-tasking (Brown, 2000). These claims have been widely critiqued as inadequately supported empirically or theoretically (Bennett et al., 2008; Jones et al., 2010; Kennedy et al., 2008), yet they have still led to calls for change in education systems in order to meet the needs and expectations of this generation of learners. Findings from most large-scale studies of youth and social media use (e.g., Ito et al., 2010; Jones et al., 2010; OECD, 2012) capture the extent of the use of social media applications such as Facebook and reveal that their use is not nearly as sophisticated as assumed (Oblinger & Oblinger, 2005; Prensky, 2001a, 2001b; Tapscott, 2000, 2008).

Research demonstrates that today's learners have high levels of connectivity. The OECD (2010) report on millennium learners shows that in the Netherlands, UK, Austria and Nordic countries, more than 95% of 15 year olds connect to the Internet daily from a home computer and across OECD countries, 73% of households with children have Internet access. Only a very small fraction of students have not used a computer (0.8%). The most recent OECD New Millennium Learners report (2012) concludes that:

> there is sufficient international evidence to support the claim that younger generations, particularly those between the ages of 15 and 24, are by far the population segment with the highest percentage of people online […] with the highest intensity of use. (p. 56)

While the OECD studies were about access, other empirical studies have shown how students' online practices are primarily social. Through surveys, interviews, study of online spaces and by closely following one group of four students for six months, Watkins (2009) concluded that young people migrate to the digital world to "maintain and enliven their off-line relationships" (p. 23) rather than to connect with strangers. In the US, in 2010, visiting social networks was the most popular activity amongst children aged 8-10 (Kaiser Family Foundation, 2010). Similarly 90% of Australian youth aged 12-19 reported using social networking services (Australian Communications and Media Authority (ACMA), 2009).

The diversity of students' uses of digital technology has been highlighted in two studies that examined different learner profiles in terms of their Internet use. Kennedy et al. (2010) identified four types of learners according to patterns and intensity of technology use: power users (14%); ordinary users (27%); irregular users (14%); and basic users (45%). Only the power users used a wide range of technology including Web 2.0 activities to any significant degree. The largest fraction of users were basic users (45%) meaning they infrequently used new or emerging technologies and used standard Web tools less frequently than the other three types of users. A similar study by Pozzali and Ferri (2010) examined general activity and participation patterns in social networks and characterized three profiles of Internet use: digital mass (40%); neo-analogical (22%); and inter-activated (30%). The digital mass included heavy Internet users, but not contributors; the neo-analogical group produced some content, yet were less dependent on the Internet than the digital mass group; the inter-activated group were those who fit the profile of 'digital natives.' The results of these studies illustrate that young people do not make up a homogenous group of 'digital natives' and use social media tools differently. However, little mention is made of social network activity for learning purposes: "contextualized rooted discussions of the potential of Web 2.0 in teaching are rare" (Brown, 2012, p. 50). More work is needed to examine factors such as gender, stage of learning, disciplinary context, and students' cultural backgrounds (Kennedy et al., 2010) for their impact on productively benefiting from high levels of connectivity.

A homogeneous generational lens has been applied to most studies of youth's online activities and there are few studies that have examined how young people's technology use changes with age. However, some large-scale studies have found that Internet use increases with the age of young people (ACMA, 2009; European Commission, 2008). And, age differences in online activities were greater than gender and socio-economic differences among approximately 25,000 children aged 9-16 drawn from 25 European countries (Livingstone et al., 2011).

Most studies of youth's social media practices commonly examine their use in social or everyday contexts (e.g., Ito et al., 2010; Watkins, 2009) and few have focused on *how* students use social media to support their learning. Studies have, for example, surveyed students' use of social media in academic contexts and the frequency of this use (Clark et al., 2009) or examined attitudes towards using social media tools (Baltaci-Goktalay & Ozdilek, 2010). A study by Bullen et al. (2009) found that undergraduate students were not sophisticated in their use of technology but that they were sensitive to appropriate use of technology in context. Student use of technology was driven by "factors such as the student and instructor dynamic within a course or program, the technical requirements of the discipline and the affordances that a tool provided within a given context" (Bullen et al., 2009, p. 10). But, to improve teaching and learning in formal educational settings, "it is the diversity of students' preferences and situations in relation to technology that matters most" (OECD, 2012, p. 12).

This brief overview of current research studies examining social media practices among youth offers an illustration of how young people *are* very connected, yet at the same time do not constitute a homogenous group. Thus, more empirical research is needed to examine *how* learners across the spectrum use social media, particularly in disciplinary learning contexts. In order to examine how the connectivity available in contemporary social media practices could lead to new learning, we frame the current research in terms of its potential for connectedness.

Complexity Thinking: Tools to Characterize Connectedness

In this paper we drew on complexity thinking as a theoretical framework for learning in order to be able to best capture how social media learning behaviours can lead to connectedness. The characteristics of connectedness described earlier are ideal for a complexity thinking framing and the area of social media and learning has largely been undertheorized to date. Thus, we propose that the suggested approach offers a powerful grounding not only for the work we report on but also for future work in the area. In an editorial for a special section of *Journal of Computer Assisted Learning* on designing and evaluating social media for learning, Ravenscroft et al. (2012) argued that we need "a much deeper and more critical discourse about design [with social media]" (p. 181). Some researchers have applied conventional analytic framing for learning to social media contexts. This has not been without criticism. In a special issue of *International Review of Research in Open and Distance Learning* on connectivism, Conole et al. (2011) compared the use of four perspectives for analysing interactions in a social network: communities of inquiry, communities of practice, activity theory and actor network theory. Conole et al. analyzed patterns of user interaction in a teaching and learning social networking site for instructors and looked for ways to evaluate the design of the site. They were interested in how to analyse emerging patterns of behaviour and found the reviewed analytic frameworks both individually and collectively insufficient for the breadth of interaction patterns identified. They concluded by suggesting that connectivism (Siemens, 2005) may be a framework to consider such emerging technologies because it acknowledges the distributed nature of knowledge and networks and that connections are built dynamically over time. However, Bell (2011) argued that, "in the current dynamic context for learning and education, connectivism alone is *insufficient as a theory* to inform learning" (p. 112, emphasis added) and proposed that connectivism should be seen as a 'phenomenon' rather than a learning theory. Williams et al.

(2011) also recognized the limitations of connectivism and designed a framework for defining and managing emergent learning using social media by combining connectivism with elements of complexity theory and communities of practice.

In our study, we would like to propose the use of complexity thinking (cf., Davis & Sumara, 2006) as a transdisciplinary conceptual framework for understanding how social media tools can prompt learning. Complexity thinking has a broad applicability in the field of education because it subsumes the social learning that occurs in communities of practice as one part of a complex system of learning and also recognizes learning at other levels of analysis (i.e., student, teacher, school, administration, cultural, etc.).

Ideas in complexity thinking in education around understanding and promoting learning are derived from characteristics of complex systems that exhibit intelligent behaviours without a centralized controller. Such complex systems have been described as learning systems (Capra, 2002) or “systems that learn” (Davis & Sumara, 2006) because they are interconnected, adaptive and self-organizing. A complex system is identifiable as a system composed of many nested individual parts, each acting in their own self-interest in an interconnected cohesive whole. This whole, which is greater (and in a sense, more intelligent) than the sum of its individual parts, has *emergent properties.* We use the term ‘emergence’ as described by Johnson (2005) as movement from “low-level rules to higher-level sophistication” (p. 18), which occurs under specific conditions (described below in Table 1).

Examples of complex systems include the Internet which is a decentralized network where many weak links and a few crucial nodes enable the swift searching capabilities of Google (Mitchell, 2009); Wikipedia, which is a self organizing network of co-created knowledge where authorship is no longer a relevant concept; and Twitter and Facebook where positive feedback loops enabled by short range relationships frequently lead to the viral spread of images or ideas. Student retention is a phenomenon that arises from a complex system of social and academic networks comprised of factors such as social norms of the university, academic performance and beliefs and expectations of the university experience (Forsman, Moll, & Linder, 2014).

Because our aim in this paper is to consider how connectivity can lead to connectedness, characterizing learning activity from a backdrop of conditions of emergence allows us to examine social media behaviour for its learning potential. We thus use complexity thinking as a theoretical perspective on learning which allows us to: (a) describe learning systems, in this case learning with social media, using characteristics of complex systems; and (b) to examine the conditions that exist that may be allowing emergence to occur. Table 1 summarizes the conditions of emergence for complex systems and we use these as an analytic framework to describe social media learning behaviours in terms of their potential to lead to connectedness, or the facility to be able to benefit from being connected. The conditions of emergence are conditions that exist within complex systems that allow for the components of the system to interact so that a whole can emerge that is greater than the sum of the parts and so that each of the participants in the system can be “smarter – that is capable of actions, interpretations, and conclusions that none would achieve on her or his own” (Davis & Sumara, 2006, p. 136).

Table 1

Conditions of Emergence in Complex Systems (adapted from Davis & Sumara, 2006)

Conditions of Emergence	Description
Internal diversity	Diversity among agents of a system increases the possible number of responses to circumstances; increases the intelligence of the system.
Internal redundancy	Duplication or excess of aspects that are necessary for interactions between agents and to compensate for agents' failings (i.e., language, skills, knowledge base); increases the robustness of the system.
Neighbour interactions	A sufficient density of representations such as ideas, hunches, queries are allowed to interact (i.e., be presented, represented, commented on), not necessarily in a specific organized structure.
Decentralized control	Control, authority, and learning are shared among agents so that the system can co-adapt and self-organize.

The conditions of emergence described in Table 1 have been used in other educational research to describe the dynamics of learning systems. For example, Davis and Simmt (2003) described how these conditions prompted the emergence of ideas among a collective of teachers engaged around the question 'What is multiplication?' Nielsen et al. (2010) designed a learning system using conditions of emergence, for teachers who supervise student teachers on practicum to explore how, through conversation (Gadamer, 1975) emergent understanding became generative for mentoring practice. And Moll (2011) identified, interpreted, and understood science identities manifested by physics students participating in physics outreach challenges using the conditions of emergence.

Methods

Our study was designed as an exploratory, interpretive multiple case study (Stake, 1995) aimed at gathering data about how physics students use social media for science learning in several contexts. In order to gather data across the physics learning spectrum data were gathered through focus group interviews with three population-based cases: secondary (grade 11 and 12) physics students, first year tertiary physics students, and upper year tertiary physics students. The purpose of the focus group interviews was to determine what kinds of social media tools students used when learning physics and how and why they used them. A range of populations were crafted into cases in order to adequately examine changes in how students use social media for learning as a possible function of their level of scientific study. The range of secondary to upper year tertiary students was chosen because it is within this range that most students start to study physics and where they are most likely to become aware of their learning processes and to begin to make decisions and choices about learning tools and behaviours that may (or may not) work for them.

The focus group interviews were carried out by one of the authors in Fall 2011. The interviews were typically about half an hour long, and took place at the school or university the participants were attending. By systematically following a semi-structured interview protocol (see Appendix A), exploratory data were collected about how the participants used social media to support their physics learning, both within and outside school contexts. The semi-structured interview protocol involved asking the participants to provide details about which social media sites they used, how they used social media and online resources when they were stuck on a physics problem, and how they saw their teachers using social media in their classes. The focus group interviews were video taped and transcribed verbatim for coding, theme searching, and interpretation. The processes of coding, identification of emergent themes and interpretation were guided by complexity thinking, and were aided with the use of the qualitative data analysis software, *ATLAS.ti* (Smit, 2003). Frequencies of use of particular social media resources were tallied and emergent themes around how resources were used were identified.

Analysis.

Conditions of emergence (see Table 1) were used as an analytic framework to characterize the nature of particular social media learning behaviours for their potential to lead to connectedness -- the ability to benefit from being connected. Social media learning behaviours reported by students were characterized for their potential to promote connectedness depending on the conditions of emergence that exist as a result of a particular behaviour. For example, chatting online is a behaviour that can promote connectedness since online chat clients provide opportunities for neighbour interactions and access to diversity and redundancy. However this is only true if chatting occurs with multiple users within the social network (such as within a Facebook group). If chatting occurs between two individuals the potential to promote connectedness would be limited. An example of a social media learning behaviour that would be very likely to promote connectedness would be creating or participating in an online group or forum where a community of individuals connect and share in order to develop an idea or create a product.

The potential for connectedness is likely to be represented by a spectrum of context-dependent behaviour that ranges from behaviours that provide multiple connections (or high connectivity) to behaviours that promote the emergence of new or deeper content understanding (connectedness) through the existence of multiple connections. Our complexity thinking analytic framework allows us to recognize the limitations of some behaviours and the potential of others to allow for emergence in a learning system.

Results and Discussion

We begin the results presentation with demographic data from our case groups of students. The aim is to characterize the groups before moving on to particular discussion of their social media behaviors in their physics classes. We identify common social media behaviors and characterize them through our analysis for their potential for connectedness.

Student demographics.

In the Fall of 2011, three types of focus group interviews were conducted with three types of physics students: secondary, first year tertiary, and upper year tertiary students. Participant and focus group demographics are given in Table 2. Data from each case were compared and similarities and differences were identified.

In each focus group, students were asked for information such as the types of technologies they had access to and their attitudes towards physics learning. This information was expected to open up the space for a more contextualized discussion of their social media use in support of physics learning.

Table 2

Demographic Data for Focus Group Participants

Focus Group Type	Number of participants	Number of Focus Groups	Other information
Secondary physics students	24 (12 female, 12 male)	5	Focus groups took place in two schools, one independent and one public school in Vancouver, BC.
First year tertiary physics students	7 (all male)	2	Focus groups took place at a small teaching university in western Canada.
Upper year tertiary physics students	3 (1 female, 2 male)	1	Focus groups took place at a large research university in western Canada.
Total	34	8	

Secondary students

The secondary students (n=24) were recruited from two different contexts. Two male Grade 12 Physics students were interviewed at an independent high school in Vancouver, British Columbia, Canada. The remainder of the sample were students who were taking Grade 11 Physics at a public high school in an affluent area of Vancouver, BC. The grade 12 students who were interviewed were taking physics because they intended to pursue engineering or business programs at university. Career motivations are a consistent indicator of students' decisions to enrol in Grade 12 Physics (Nashon & Nielsen, 2007). While some grade 11 students had similar science or math career aspirations, their reasons for taking physics were more varied: some took it to keep their options open and others because it was expected in their peer group or by their parents. More students found physics difficult (13/24, 54%) than easy (8/24, 33%) (three students did not respond), but most had neutral or moderately positive attitudes towards physics. Focus group interviews were held in October when most of the participants were just two months into their first dedicated physics course (Grade 11 Physics). Thus, student attitudes towards physics had not had much time to develop beyond the initial elective choice to enrol in physics at the high school level. All secondary students who participated in focus group interviews owned their own computer, almost half (11/24, 46%) owned a smartphone and some (5/24, 21%) used an iPod Touch or tablet to access the Internet. Most students (18/24, 75%) said that they were members of Facebook and had been since middle school (Grade 7 or 8). Throughout focus group interviews, the frequency of the students' use of Facebook was highly varied.

Tertiary students

There were three focus groups of tertiary physics students, with a total of ten participants. Tertiary students fell into two sub-groups: upper-year students and first-year students. The upper-year sub-group consisted of three students who were finishing Honours physics degrees at a large research-intensive university in western Canada. All of these students owned their own computers and were members of Facebook. Two students also used a smart phone device to access the Internet.

There were two focus groups with first-year physics students with a total of seven participants, all of whom were male and were recruited from introductory physics courses at a small teaching university in western Canada. Most of these students were studying science but had not yet declared their majors, expressing interest in studying physics, computer studies, engineering or biology. While most first-year students were taking physics as a required course in their science degree, some said that they were interested in physics and enjoyed it. Thus, this group of physics learners, who volunteered to participate in the study, had generally positive attitudes towards physics. Similar to the high school students, interviews with first-year tertiary students were conducted early in the semester and thus students had just started their first tertiary level physics course. All seven of the first year students owned their own computers, some (3/7, 43%) owned a smartphone, and most (6/7, 86%) were members of Facebook.

In summary, across the three types of physics learners, student demographics with respect to technology use were similar: all students owned their own computers; most, but not all, were members of Facebook; and about half owned smartphones. These findings are consistent with large-scale surveys of students in these age groups (e.g., Clark et al., 2009; Watkins, 2009) where it has been found that Facebook use is prevalent and that not all students have access to mobile technologies.

Use of social media resources.

When students were asked to describe the types of social media resources they used for learning physics, students named a wide variety of resources. The most frequently named resources are listed in Table 3. Note that not all the resources in Table 3 are social media tools (i.e., bookmarking), but all can be used in social media kinds of ways (i.e., Delicious for social bookmarking). Where tallies are higher than total student numbers this means that the resource was mentioned more than once.

Table 3

Frequency that social media resources were mentioned by students (n=34) in focus group interviews.

Resource	Frequency	Resource	Frequency
Facebook	54	Course Management Systems	9
Videos (i.e., YouTube)	38	Bookmarking	7
Online forums (i.e., Yahoo Answers)	34	Skype	6
Google	27	Wolfram Alfa	5
Twitter*	17	Cloud Computing	4
Wikipedia	15	Reddit	4

*Our findings indicated that students do not use Twitter much (socially or academically) but Twitter was discussed in each focus group because the researcher asked about it.

Student use of Facebook, videos, online forums and Google were high, thus some trends and interpretations about social media learning behaviours with each of these resources are discussed next. Similarities and differences between secondary and tertiary students are discussed within each theme.

Connecting with peers: Homework chatting on Facebook.

Facebook was the participants' primary resource for communicating with other students. It was preferred to email and some of the secondary students said that they did not know their close friends' email addresses. For example, "Yeah, I don't check it [my email] every day. If you want an instant response, you would Facebook message someone" and "I still have to check it [my email] sometimes because teachers like using it."

Given that Facebook is a major communication resource, the students often used it to chat online about their homework and assignments. When the students were asked what they did when they were stuck on a physics homework question 24/34 (71%) said that the first thing they would try was chatting online with a friend. While Facebook was the most frequently used chat client, the students also indicated that sometimes other tools were used such as MSN or Skype. The students indicated that chatting online about physics homework was often challenging, particularly when equations and symbols were needed. One student said: "it's sometimes hard to get the symbols but usually in First Year [university] it's just *v* or *m.*"

Secondary and tertiary students talked about Facebook in similar ways, and with similar frequency and emphasis. For all of the groups interviewed, Facebook played an important role in the ways their social network supported their academic work. These results echo a prevalent finding in the literature that students are adept at using social media resources to support their existing social interactions (e.g., OECD, 2012; Watkins, 2009). Focus group data indicated that students mostly use Facebook chat to connect individually with peers to ask questions about homework. This is evidence that they are taking only limited advantage of other features of Facebook that could provide more support for their academic learning. Using chat functions in Facebook or MSN provides immediate support between two students, but this activity may not provide lasting support or support connections to a larger learning community. Thus, the reported use of chat functions is unlikely to promote a more decentralized and self-organizing system. Further, it is unlikely that anything unanticipated or new will emerge, thus this social media learning behaviour is characterized as limited in its potential to allow for connectedness.

Facebook could foster connectedness. Posting a question to an online forum or a Facebook page that reaches out to a group of students could be a social media learning behaviour with a higher potential to lead to wider discussion of ideas and new or deeper content understanding. Using Facebook in this way provides a less centralized medium for *neighbour interactions* (e.g., students' and teachers' ideas) than a classroom. Walker (2012) documented that students do create Facebook groups to meet and discuss course content, however, none of the students in our study said that they had done this.

When asked for suggestions about how their teachers could fruitfully use social media in their teaching, the students in our study most frequently named Facebook. Some of the tertiary students offered anecdotal reports of professors who had used Facebook to communicate with their students, usually through a Facebook group or page. Both secondary and tertiary students suggested that teachers should develop a presence on Facebook, usually so that they could be more accessible to answer their students' questions, as noted by this first-year tertiary student:

> I think it would be cool if they had like a Facebook because they only have a certain amount of office hours. But if you were on Facebook, you could just talk to them anytime you want kind of thing. And it's a lot quicker than email. And you wouldn't have to wait for them.

This and other examples from our focus group data illustrate how students still rely on a traditional model of schooling, where knowledge and expertise primarily lies with the teacher, and is in line with literature reporting that students' expectations about school have not changed dramatically in spite of their connectivity (e.g., Bennett et al., 2008; OECD, 2012). Thus, while participating students demonstrated a high level of connectivity in their use of social networking resources such as Facebook, our data indicate that the social networking resources are used in ways that make learning more convenient and efficient, which we interpret as social media behaviours that have low potential to lead to connectedness. To create conditions of higher potential for establishing connectedness, social media learning behaviours on Facebook or Twitter could, for example, connect students to a wide array of perspectives, allow and encourage the co-construction of knowledge and develop more complex support networks through such tools as Facebook groups.

Accessing a diversity of explanations: Watching online videos.

YouTube and other video sharing platforms offer social media capabilities for members to create and/or share content; curate channels of content; and connect with others and comment on videos. Our focus group students accessed videos as a social media resource and described how they used digital videos to help them to learn physics.

The most prevalent use for videos amongst the secondary students was to help find the solution to a problem. A little more than half (13/24, 54%) of the secondary students specifically cited online videos as a resource that they consulted when stuck on a physics problem. For example, one secondary student said: "[when I'm stuck on a physics problem] I'll YouTube it. I look at the chapter, the questions in it and usually there's a video, like a math tutor." In contrast, tertiary students were more likely to use videos in more sophisticated ways, for example, to clarify or review physics concepts or to learn more about a concept, as noted by these students:

> I usually [watch MIT lecture videos] when it's [physics content] really confusing….not only are they good for Physics but I also find they have put a bunch of other ones as well.

> I think most of my learning that I get done is in the classroom setting, but these videos seem to be refreshing, like just to remember what you've done before.

Some of our participating students appreciated the visual mode offered by video, as suggested by this secondary student:

> For me, overall, to watch something in a video, I learn a lot from that instead of just listening. It's the same thing if the teacher does an experiment: it's easier to understand and to learn. So, if I watch a video on YouTube, I learned it a lot easier.

Most of the videos students viewed were 'chalk and talk' style lectures and rarely did they access simulations or animations. Videos typically present information in a similar manner to lectures, so why do students sometimes prefer watching videos? A first-year tertiary student explained the appeal of videos: "I think the big thing about having media to do that is, you know that you could access it anytime you want…Like I can't tell a prof, 'You want to stop now?'…with videos I could." Out of a perhaps naïve perspective, secondary students preferred videos to their classroom teacher:

> S1: [Videos help me learn] because when we're in class we have to listen to the teacher but we have the choice not to because we don't really want to. And then when we're self-studying, like when we're on the computer, we're focused on one point. So I guess we're concentrating on that video or information.
> S2: The video gives much more information.
> S3: You can't exactly press pause on the teacher and go back.

Secondary and tertiary students described similar reasons for frequently accessing online videos to support their physics learning. However, tertiary students were more likely than secondary students to say that videos helped them to deepen their learning of a concept. Convenience and flexibility of use (when, where and how they watch the videos) were the most dominant themes. Similar to the way students used Facebook, most secondary students also accessed YouTube to find online videos that would provide answers to homework questions.

Using social media resources as a way to seek convenient and immediate answers to specific homework questions can be characterized as having limited potential to lead to connectedness. The behaviours do not encompass any of the conditions of emergence described in Table 1. We argue that students are unlikely to significantly benefit and develop new and deeper content understandings when they are watching videos to replace classroom learning or to find the answers to specific homework problems.

In order for online video use to be characterized as having the potential to lead to connectedness, students could share videos with one another, bookmark and curate them to review later, or explore a concept in more depth than was presented in their texts or classes. These behaviours could lead to the emergence of a decentralized network of videos that students could access as a resource for their learning and would thus improve the quality of the neighbour interactions (sharing of ideas) between students.

During focus groups, students were asked if they bookmarked or shared videos they had found helpful. Most students said that they had not done this. However, there were instances where students demonstrated an awareness that videos could be used in more sophisticated ways. For example, several students said that one could find a video lecture on almost anything online, but recognized that many of these "need to be compiled better" and that "a professor knows if a video is actually true." Thus students recognized that their learning could benefit from accessing a more organized pool of video resources.

Several of the secondary students talked about online tutoring communities such as the Khan Academy (https://www.khanacademy.org) that have videos and worksheets, and had found them very helpful for independent learning: "He [the Khan Academy presenter] has notes and stuff as well, so that while you're watching the videos you can look at his notes and stuff". However, few students said that they were members or regular users of the Khan Academy learning community. Using a complexity thinking perspective on learning, we propose that if students access videos as part of a learning community such as the Khan Academy (or a YouTube channel) on a regular basis, they could become connected to that community and potentially benefit because the community likely has both a diversity of ideas to help solve problems and redundancy of skills such as each member of the community has watched the same set of videos to learn about a particular topic. These are two conditions of emergence (Table 1) that can create meaningful connections between individuals that may allow for emergent learning to occur. Thus, the results of student use of videos are similar to those for Facebook and likewise limited in their potential to promote connectedness.

Looking for the right answer: Online forums and Google.

While students from both secondary and tertiary education contexts tended to use Facebook and online videos in similar ways, student use of online discussion forums was markedly different between these two groups. More than half of the secondary students (13/24, 54%) said that they used online forums or Question & Answer sites such as Yahoo Answers or Answers.com, whereas only 3/10 (33%) tertiary students said that these kinds of sites were helpful, and all of these were first year students. None of the upper year tertiary physics students mentioned these sites. Secondary students also relied more heavily on Google (25/34, 74%) than tertiary students (5/10, 50%). One first year tertiary student said that he liked using this strategy because "You can type in exactly what you want to know and you can find it out." A secondary student described his strategy: "I just Google a really stupid sentence, question like, "How do you do this Physics question?" And then see if it's on Yahoo answers." During their focus group, other secondary students discussed using an online forum:

> S1: I'll type something in [to Yahoo Answers] and usually someone's asked that question.
>
> S2: There's also, if you ask a question and wait for someone to answer…if you want some more answers.

However, secondary students also recognized that it was difficult to "Google" the answers to physics questions, as noted in these examples: "The equations ones, they're really hard to find some of the answers. It's like, 'Oh, my God! I don't understand what I'm doing!' and "If it's stuff like that where I can't really Google it then, I just ask my online friends."

So, although many students recognized that Googling for physics answers does not work very well, the majority of secondary students still said that it was a strategy that they frequently used. This result is consistent with research literature around students' use of technology indicating that today's students increasingly want immediate, easy to find, and surface level solutions (e.g., Center for Information Behaviour and the Evaluation of Research, 2008; Clark et al., 2009). Our focus group data for students' use of online forums supports this literature. And unfortunately, students' awareness of the limitations of a strategy does not necessarily lead to other strategies. However, our participants were twice as likely to ask a friend (usually via online chat) in preference to visiting Google or Ask.com. We see this as evidence that students prefer person-to-person interaction to anonymous information-sharing on the Internet.

Few students in our focus groups described using online forums in ways that could be described as having the potential to lead to connectedness. For example, as noted, students rarely contributed to online forums by answering questions or commenting on others' answers. Thus, they did not use online forums to receive or provide feedback to a learning community, which would help a decentralized system adapt and evolve so that new ideas or content understandings could develop. When it comes to finding information and using it to help them with their homework, the majority of the secondary students typically used the Internet, and more specifically social media resources such as Facebook, online videos and online forums, in a mostly Web 1.0 way. Tertiary students, on the other hand, particularly the upper-level students, were more likely to use social media and seek online resources to gain a deeper understanding of a concept rather than simply looking for the right answer. This first-year tertiary student described the difference between learning using technology in high school and in university:

> In high school, the teacher gave you a lesson and you just kept that and you just stay there. You don't go beyond that. Here [at university], you have to go…I have to go beyond that. So I have to look for other sources to get more information and support my knowledge. It helps us to know more about it even if it's not relevant to answering the questions. So you're not just parroting things back.

This tertiary student is describing a more sophisticated use of social media and online resources than the majority of our participating students (secondary and tertiary). The use of social media resources to actively try to deepen conceptual understanding is a social media learning behaviour that can be characterized as having some potential to promote connectedness. However, this student did not describe many concrete strategies or resources that they actually used to pursue deeper content understandings. So while apparently recognizing the possibilities of social media to contribute to their physics learning, even tertiary students may lack the skills and strategies to act on their learning goals.

Conclusions and Recommendations

This study aimed to examine secondary and tertiary students' self-reported social media behaviours in physics learning contexts. On the whole, we observed few social media learning behaviours that had potential for connectedness. Participants frequently used social networking tools such as Facebook, online videos and online forums, but their social media learning behaviours were limited in terms of potential to promote connectedness. Secondly, there are both similarities and differences between the ways secondary and tertiary students used social media to support learning. Both groups used Facebook in similar ways; video was used in slightly more sophisticated ways by the tertiary students; and the social media learning behaviour of searching online forums for the right answer was primarily limited to secondary students. These results support claims in the literature that 'today's youth' do not represent a homogeneous group (Kennedy et al., 2010; Livingstone et al., 2011; Pozzali & Ferri, 2010) and that experience with social media resources does not necessarily lead to sufficient connectedness for a meaningful and effective harnessing of those resources for new or enhanced learning. It was encouraging to observe upper-year tertiary physics students exhibit social media behaviours that had some potential to lead to connectedness. However, through our perspectives in complexity thinking, we found no mention of behaviours having high potential for promoting connectedness. The conditions of emergence lead us to suggest that social media behaviours such as creating communal spaces online to share digital resources could be fruitful for establishing and extending academic collaboration.

For each frequently used social media resource that students described, their behaviours were limited in potential to lead to connectedness because the behaviours did not promote many connections with a wider learning community. Based in the conditions of emergence, we suggested social media learning behaviours that have higher potential for connectedness for each social media resource. The conditions of emergence are a potentially fruitful way to consider how social media learning behaviours could facilitate deeper content learning through connectedness. We see this as an important scaffolding role for educators: introduce new digital tools into the learning context and to scaffold students' use of those tools so that they learn to recognize and work with the potential of the tools to benefit from their high levels of connectivity. We thus build on a key recommendation in the OECD (2012) report which acknowledges that schools need to draw on students' expertise in achieving connectedness in their social relationships in order to also support their academic learning. As educators, we can build on students' familiarity with constructing and maintaining effective social networks and if we understand how students interact socially online, we can start to find ways to scaffold connections to their existing social networks that effectively support their academic learning.

Finally, this article has employed a complexity thinking perspective on learning to interpret the ways students use social media and offers recommendations for enhancing connectedness using social media tools that students already have. We suggest that complexity thinking, as a theoretical perspective on learning, could offer recommendations for the design of learning activities using social media in order to increase the possibility of emergence through considering neighbour interactions, decentralized control, diversity, and redundancy into the learning system. For example, if a teacher knows that students frequent online forums such as Ask.com, they could incorporate its use into a homework assignment – asking students to contribute to questions asked on a particular topic, or to critique others' submissions. In so doing, students would be participating in a learning community that has the potential to contribute to their understanding of physics content. In significant ways, this advances their participation beyond simply observing and drawing passively from the community's resources. Research in the area of social media learning behaviours needs to examine behaviours in more detail in particular learning contexts, and needs to use theoretical perspectives of learning that offer recommendations for emergent learning behaviour.

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Appendix A – Focus Group Protocol

Demographics:

- What grade are you in?
- What physics courses are you taking or have taken?
- Do you find physics easy or difficult?

Computer literacy and access:

- Do you own your own computer/laptop?
- What other devices do you use to access the internet (cell phone, ipad etc..)
- How much time do you estimate you spend on the internet each school day? And on weekends?
- How do you define social media?
- Which social media sites do you belong to?
- Which social media sites do you access regularly?
- Listing popular social media sites ask them to rate how often they access them (several times a day, several times a week etc…). Ask about Facebook, My Space, Twitter, Youtube and others that emerge from background research.
- What social media sites do you access but don't belong to (i.e., don't participate)?
- How old were you when you had your first email address?
- How old were you when you first joined a social media site?

Social media and science learning

- When you're stuck on a physics problem or concept what do you do first?
- Who do you go to for help?
- What online resources do you access regularly? And why?
- Do you ever connect with or get help from people you've never met on the internet to work on physics questions?
- Do you work with classmates online on physics problems/projects?
- Do you think social media and online resources should be used to teach physics? Why or why not?
- Do your physics teachers ever use social media when they teach? If so, in what way?
- What types of social media do you think they should use? And how should they use it?
- What have you learned about physics online that you haven't learned about in your classes?
- Is there an online resource that helped you to understand a physics concept in a more effective way than traditional lectures, texts and labs have?