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Interactive learning in an urban environmental education online course

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Interactive learning in an urban environmental education online course

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Online courses play an increasing role in professional development of environmental educators, yet little information is available on the interactive processes involved in online learning. We examined the relationship of three types of interactions in an urban environmental education online course – participant–participant, participant–instructor, and participant–content – to four course outcomes: participants' motivation to learn, intent to adapt ideas and information learned through the course in their practice, actual adaptation of ideas in their practice, and development of professional networks. Content analysis was used to characterize participants' and instructors' weekly online posts and comments, and generalized estimation equation modeling was used to explore the relationships between interactions and outcomes. The results showed that participant–content interaction had significant positive relationships with participants' motivation to learn, intent to adapt ideas, and adaptation of ideas. Participant–participant interaction had significant positive relationships with participants' motivation to learn, and development of professional networks with each other. Finally, participant–instructor interaction had a significant positive relationship with participants' development of professional networks. The results of this study can be used to improve professional development online courses for environmental educators.

Keywords: environmental education; online learning; professional development; interactive learning; professional networks

Introduction

As online courses become increasingly popular, course designers are searching for ways to create learning experiences that move beyond content acquisition to incorporate meaningful interactions among learners and between learners and instructors (cf. Alexander, Schallert, and Reynolds 2009; Illeris 2007; Sfard 1998). Interactive theories of learning would support such experiences, including theories focusing on how students construct knowledge through processes of assimilation and accommodation (Piaget 1952) and how participants move from an inexperienced to skilled member of a community of practice (Lave and Wenger 1991; Rogoff et al. 2003; Wenger, McDermott, and Snyder 2002). Related theories focus on the social, cultural, and historical contexts of learning (Lemke 2001), and on the importance of reciprocal interactions among learners' behaviors, capabilities, and surrounding environment (Bandura 1977).

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Whereas environmental education scholars have described interactive learning using the lenses of social learning (Wals 2007; Wals and van der Waal 2014), eco-logical theories of learning (Chawla 2008), and activity theory (Krasny and Roth 2010; Lee and Roth 2003), interactive theories of learning do not seem to have per-meated the research on online professional development courses for environmental educators. Rather evaluations of online courses in environmental education have focused primarily on content, confidence, and motivation outcomes, with some men-tion of challenges in promoting social learning environments online. For example, studies of the University of Wisconsin–Stevens Point environmental education pro-fessional development courses have demonstrated an increase in course participants' environmental knowledge and skills (Cordie 2009; Dillard 2006; Lockman 2006; Wang 2007; Wilcox 2004; Zbleski 2001) as well as in their confidence to teach (Dillard 2006). The evaluation of the national environmental education program Project Learning Tree's online workshop found that participants were motivated to use learned activities in their practices (McConnell and Monroe 2012). Fleming and Easton (2010) point out challenges in teaching online courses for environmental educators, including attrition rates and creating a social learning environment. Stud-ies of online courses focused on environmental issues rather than environmental education per se have demonstrated that participants not only increased environmen-tal knowledge and attitudes scores (Aivazidis, Lazaridou, and Hellden 2006), but also point to the success of courses in engaging students in interactive learning (Eckelman et al. 2011; McCormick et al. 2005; Vann, Pacheco, and Motloch 2006). However, we are not aware of any studies that applied social learning, communities of practice, or other interactive learning frameworks to online learning in environ-mental education or professional development of environmental educators.

Given that online education for the professional development of environmental educators may seek different outcomes than other online courses, and that the University of Wisconsin–Steven Point and Cornell University have offered online courses in over 20 different subjects with funding from the US Environmental Protection Agency, we felt it was important to address the question of how to align online professional development courses with interactive learning theories reflecting a tradition of interactive learning in environmental education. The online course that is the focus of this study is part of the North American environmental education pro-fessional development program, EECapacity (http://www.eecapacity.net/). Rather than attempt to disseminate established practices to educators, EECapacity online courses and other professional development activities are based on the assumption that bottom-up or grassroots innovations (Seyfang and Haxeltine 2012) are critical, if environmental education is to address the challenges posed by climate change, environmental degradation, and associated declines in individual and community well-being. Further, EECapacity draws heavily from the social innovation literature, which suggests that innovations in educational practice emerge through creating platforms for exchange of ideas and resources among educators holding different perspectives and practices (Moore and Westley 2011; Mulgan 2006). Our online courses reflect EECapacity's social innovation philosophy and incorporate opportu-nities for course participants, whose environmental education practices vary widely, to exchange ideas and resources as well as to learn from resources supplied by the instructor. Thus, the outcomes that are important to our online courses include whether participants are motivated to learn, whether they adapt what they learn from

interactions with the instructors, content, and participants to their own settings, and whether they form idea and resource-exchange networks with other educators.

To enhance our understanding of the process of online learning in environmental education, we conducted a study of the relationships between different types of interactions and outcomes in an urban environmental education online course offered by Cornell University in fall 2011. More specifically, we investigated the relationship between participant interactions with other course participants, with course instructors, and with course materials, to four participant outcomes: motivation to learn, intent to adapt ideas and information learned in the course in their educational practice, actual adaptation of ideas in their practice, and development of professional networks.

Literature review

Interaction refers to reciprocal processes involving at least two participants (Wagner 1994) through which negotiation of meaning and construction of knowledge occurs (Gunawardena, Lowe, and Anderson 1997). In online learning environments, interactions are described as involving the content, facilitators and participants, and context (Berge 1995). Interaction in online courses may be synchronous or asynchronous (Banks et al. 2003). Asynchronous interactions allow more time for participants to think (Kaye 1992) and contribute to the discussion more equally (Ingram and Hathorn 2004), and are better suited for deeper discussion of ideas (Smith 1994).

Scholars of online learning have offered various classifications for online interactions. Moore (1989) suggests three basic interactions in distance learning: (1) participant–content interaction, which is largely self-directed and in which participants learn from written and recorded materials such as journal articles and videos; (2) participant–participant interaction, which may include peer tutoring (Rourke and Anderson 2002) and collaborative learning (Graham and Scarborough 2001), and in which participants make comments to each other and work on group projects; and (3) participant–instructor interaction, through which participants communicate with instructors and receive feedback (De Laat et al. 2007b; Moore 1989). With the increasing use of communication technologies, Hillman, Willis, and Gunawardena (1994) add learner–interface interactions, referring to the medium with which participants interact in a distance education environment, which may impact learners' interest, performance, and course satisfaction (Metros and Hedberg 2002; Rubin, Fernandes, and Avgerinou 2012). Anderson (2008) proposes six forms of interaction: participant–content, participant–teacher, participant–participant, teacher–content, teacher–teacher, and content–content, and suggests that different forms may be substituted for each other, depending on costs, content, learning objectives, convenience, technology, and available time; whereas Jung et al. (2002) classifies online learning interaction more broadly as academic, collaborative, and social.

Studies of online learning in non-environmental education contexts reveal that different sorts of interactions are associated with different outcomes. For example, interactions of participants with instructors can motivate students to learn (De Laat et al. 2007b; Moore 1989) and encourage more active course participation compared to participant–content interaction only (Andersen 2013; Hong 2002). However, Kang and Im (2013) caution that social interactions between instructors and participants, such as social intimacy, could negatively affect participants' achievement and

satisfaction. Interactions of participants with other participants and with their instructors facilitate consideration of alternative viewpoints; this in turn may foster an awareness of one's own knowledge (Veldhuis-Diermanse 2002), and enhance participants' course satisfaction (Gunawardena and Zittle 1997; Northrup 2002). Finally, Graham and Scarborough (2001) report that participant–participant interaction, and in particular collaborative learning, is positively associated with participants' online learning experience; and Jung et al. (2002) find that participant–participant interaction relates to the highest level of course satisfaction.

Several studies have applied social network analysis (Scott 2000) to quantify interactions between participants and instructors in non-environmental education online courses (Nurmela, Lehtinen, and Palonen 1999; Reffay and Chanier 2002). For example, a study of primary school students engaged in online learning reveals that the density of interaction (the extent to which participants are engaged in online communication) is high; 39% of students interacted with others. Further, out-degree centralization (comments sent to others) is higher than in-degree (comments received from others), suggesting uneven participation among the students (Lipponen et al. 2003). In addition, some studies investigate the impact of these interactions on participants' learning performance. In a study of university online learning, Cho et al. (2007) found that both individual and structural factors impacted participants' development of learning networks, which in turn were correlated with their learning outcomes. For example, the central actors in a collaborative learning online network tended to achieve higher final grades than others (Cho et al. 2007). Studies by De Laat and colleagues (2007a, 2007b) combined content analysis and social network analysis to examine online learning and tutoring processes, and how participatory patterns change over time within a networked learning community, and concluded that teachers can play an important role in encouraging interaction among participants by creating a climate of openness and supportive structures for learning.

Researchers have conceptualized teacher development from different perspectives (Desimone 2009). From the cognitive perspective, teachers acquire skills and knowledge in one setting, which they use elsewhere in a process of transfer (Wenger 1987). A situated learning perspective maps program content, facilitators, teachers, and context to the quality of professional development (Borko 2004), whereas a social constructivist approach focuses on conceptual change, reflection on practice, and intuitive knowledge in teaching practice (Adey 2004). Shulman and Shulman (2004) proposed a framework that includes vision, motivation, understanding, practice, reflection, and community, and suggested that motivation to learn and change is an essential component of teacher development. Finally, Bell and Gilbert (1996) proposed a model for teacher learning processes that includes personal, professional, and social development.

Professional development of environmental educators addresses not only knowledge acquisition, but also helps educators adapt ideas and information learned to improve their environmental education practice (Boud and Hager 2012; Panda and Juwah 2006). Such adaptation includes examining new practices, adapting innovations as appropriate to the needs of learners, and reflective use of innovations (Mevarech 1995). Development of professional networks is a key component of educators' social development, including through web-mediated learning environments such as online courses, professional learning communities, and social networking sites. Social networks may enable the mobilization and transfer of

knowledge, and therefore can play a key role in the dissemination of educational and other social innovations (Moore and Westley 2011).

Research question

While past online learning studies have investigated interaction among participants and various course outcomes, we are not aware of any studies in environmental education exploring the relationship between online interactions and professional development outcomes. The research question addressed in this study is: what is the relationship between interactions within the online course and professional development outcomes? More specifically interactions within the online course include participants' interactions with each other, course content, and course instructors. The professional development outcomes include participants' motivations to learn about environmental education practice and research, intent to adapt ideas and information from the course to their own programs, actual adaptation of ideas and information from the course in their practice, and development of professional networks among participants.

Methods

We used a combination of content analysis and generalized estimation equation models to code and analyze the data, which consisted of participants' weekly posts and comments to the online course website.

Online course and study participants

The Cornell University online course *Environmental Education in Urban Communities* was offered for the first time in September–December 2011, using the Course-Sites online course management system. The course was developed by the second and third authors in collaboration with an urban environmental educator, and was taught primarily by the third author with assistance from the second author.

Among 175 course applicants, we selected a total of 25 (20 females and 5 males) environmental educators from across the US to participate in the course. Selection criteria included geographic diversity, expressed commitment and interest in the course, and potential to contribute diverse perspectives to the discussion of urban environmental education. Educators represented a variety of organizations including K-12 schools, universities, community-based organizations, nature centers, and city parks departments. Participants' experience as educators ranged between 2 and 30 years (mean = 12 years). All participants except one completed the course.

The course participant learning goals were as follows: (1) learn about a variety of approaches and outcomes of environmental education in cities, (2) understand how environmental education research can improve practice, (3) develop and exchange activity plans that are research-based and can be used in your job with diverse audiences, (4) contribute to the development of new national Guidelines for Excellence in Community Environmental Education, and (5) build a network of peers working in environmental education in urban settings. During the 12-week course, the instructors encouraged collaboration and sharing of ideas among the participants through online asynchronous discussions of research findings, participants and instructors commenting on participants' assignments, participants creating draft

Table 1. Course assignments and materials.

Week	Topic	Materials	Assignment
1	Introduction	Videos	Self-introduction
2	Urban environmental education case studies from the Bronx	Videos, narratives	Reflection*
3	Urban environmental education theory	Concept map example	Concept map
4	Environmental education outcomes research	Research articles	Reflection
5	Diversity of audiences, environmental justice	Research articles	Reflection
6	Environmental education curricula and approaches	Videos, curricula	Reflection
7	NAAEE Guidelines for Excellence	Videos, NAAEE Guidelines for Excellence	Reflection
8	Lesson plans	Lesson plan example	Lesson plan
9	Research on behavior	Research articles	Reflection
10	NAAEE Guidelines for Excellence	NAAEE Guidelines for Excellence	Informal guidelines
11	Urban environmental education theory	NA	Revise concept map
12	Course wrap-up	NA	Wrap-up

*Reflection assignments asked educators to comment on how course materials (videos, narratives) helped them conceptualize and reflect on their own practices.

guidelines in urban environmental education, and participants developing and exchanging lesson plans. For weekly assignments (Table 1), participants were asked to watch videos or read materials on topics including environmental education in cities, environmental justice, diverse audiences, behavioral change, and the Guidelines for Excellence (NAAEE 1998–2004). Participants also were asked to post their reflections on how course materials (videos and narratives) helped them conceptualize and reflect on their own practices, as well as to post at least two comments on other participants' posts on the course website every week. The instructors commented on participants' weekly posts. All assignments were individual except for one small group assignment to develop informal guidelines for urban environmental education.

Coding methods

Coding schemes

We used course participants' weekly posts on the course website as an indicator of participation (Lipponen et al. 2003). We coded participants' posts and comments for the nine weeks of the course that included significant whole-group interactions, excluding weeks 1 (introduction), 7 (small group work via email and phone, without online discussion), and 12 (wrap-up). The posts included weekly reflections on the written and video course materials, as well as responses to other participants' reflections. Using content analysis (Neuendorf 2002; Rourke et al. 2001), we coded for interaction (defined as interactions of participants with content, other participants, and instructors) and outcomes (defined as motivation to learn, intent to adapt ideas, adaptation of ideas, and development of professional networks, Table 2). While

Table 2. Interactions and outcomes coding scheme: definitions and examples.

Code	Description/quotes
Participant–content interaction	Participants write about course materials such as videos, narratives, curricula, and research articles
Participant–participant interaction	Participants share ideas and experience with other participants and comment on others' posts and comments
Participant–instructor interaction	Participants communicate with instructors and receive feedback from instructors' comments
Motivation	Developing and maintaining one's willingness to learn. 'I would be interested to hear more research on youth development, stewardship, community building'
Intent to adapt	Intent to adapt the learned idea into one's practice 'This is reassuring and I'm going to use this in any grant applications I have for the High School Urban (program name) program!'
Adaptation	Adapted idea from the course into one's practice during the course 'I have tried to incorporate many of the ideas I have been exposed to in this course in my community action research class for 9th graders'
Network	Intent to develop professional networks with other participants or instructors 'We should talk about … We should write a grant and get you a green roof … I'll gather the info and maybe we can chat in (XX City) or I can come visit you'

considering various approaches to unit of analysis in coding such as single sentence (Fahy et al. 2000) or complete message (Gunawardena, Lowe, and Anderson 1997; Rourke et al. 2001), we chose to code for a consistent 'theme' or 'idea' (unit of meaning) in a message or online post (Henri 1992), which was generally a paragraph or several sentences. For example, if one paragraph described a specific learning resource like a video, we coded the whole paragraph as 'participant–content interaction.' In addition to an interaction code, if one or more outcomes were evident in the same paragraph, we would assign outcome code(s) (e.g. motivation, intent to adapt, adaptation, and/or network). If there were multiple interactions or outcomes showing in the same paragraph, multiple codes would be assigned to the paragraph.

Validity and reliability

Content validity was addressed by using previous studies and expert opinions to develop the coding scheme for the content analysis. Convergent validity was examined by comparing the content analysis to a post-course evaluation survey, which revealed results showing that intent to adapt practice and networking were important course outcomes. By the end of the course, 25% course participants had already incorporated what they learned into their practice, 76% intended to adapt ideas into or expand their practice, 42% indicated that the online course facilitated information sharing among course participants, and 46% said that their professional networks had expanded within and beyond the course (Russ, unpublished data).

To test for the reliability of our coding scheme, the first author and a colleague coded a subset (one week) of the participants' online posts and we calculated

percent agreement, or the ratio between the number of agreed codes and the total number (agree + disagree) of codes (De Wever et al. 2006; Lombard, Snyder-Duch, and Bracken 2002; Riffe, Lacy, and Fico 1998). Scholars suggest that the acceptable range for inter-coder reliability is above 80% (Riffe, Lacy, and Fico 1998) or above 85% (Saldaña 2009). In our case, inter-coder reliability percent agreement for codes ranged from 90 to 100%, except for motivation, which was 85%.

Models and variables

After coding the nine weeks of posts and comments, we organized data by 24 participants over 9 weeks, resulting in a possible 216 observations for the regression analysis. Specifically, for each participant in each week, we recorded the frequency of three types of interactions, the frequency of four types of outcomes, the frequency of receiving comments from other participants and instructors, and the time rank indicating when each participant posted the assignment. In some weeks, a few participants did not post their assignments and comments; thus, we had a total 202 observations instead of 216.

To estimate the relationships between interactions and outcomes using the non-normal data and to control for the non-independence of the observations due to the fact that each subject was repeatedly measured over 9 weeks, we used a generalized estimation equation model (Halekoh, Højsgaard, and Yan 2006) with binomial distribution, and a logit link and autoregressive correlation structure over the weeks. For the purposes of the model, we labeled the interactions as independent variables, and the outcomes as dependent variables, while recognizing the model cannot prove causation. In addition, we added five variables that might influence the results, frequency of receiving comments from other participants and instructors in the previous week, week, time-rank, and work-year to the models. Frequency of receiving comments from other participants and instructors in the previous week could affect participants' performance. Week means the progress of the course; for example, the value 2 would be the second week of the course. Time-rank is the time order of participants' posts in each week; for example, the value would be 1 for the first participant who submitted the assignment in a specific week, and the value 24 for the last person who submitted the assignment. Time-rank could affect participants'

Table 3. Descriptive statistics.

Variables	Minimum	Maximum	Median	Mean	Standard deviation
Motivation	0	5	0	0.564	0.924
Intent to adapt	0	5	0	0.639	0.937
Adaptation	0	1	0	0.040	0.196
Network	0	2	0	0.079	0.289
Participant–content interaction	0	10	3	2.643	2.295
Participant–participant interaction	0	10	2	2.718	1.808
Participant–instructor interaction	0	1	0	0.084	0.278
Work-year	2	30	10.5	11.767	7.365

Note: Number of observation = 202.

performance as when earlier posters get more comments from others, but may be less likely to read others' posts. Work-year is the number of years each participant has worked in environmental education; years of experience could affect a participant's reaction to the given learning materials, other participants' posts and comments, and the instructors' comments.

Participant–content interaction and participant–participant interaction were coded as continuous variables based on number of times a participant interacted with course materials or with other participants within a particular week. Because interactions with instructors were less frequent, we coded participant–instructor interaction as a binary variable, based on whether or not a participant's posts demonstrated interaction with the instructor within any one week. All four dependent variables were coded as binary (present/not present) (Table 3).

Results

The models showed that participant–content interactions had a significant positive relationship with motivation to learn, intent to adapt ideas, and adaptation of ideas, whereas participant–participant interaction had a significant positive relationship with participants' motivation to learn and development of professional networks. In contrast, participant–instructor interaction had a significant positive relationship with only one outcome; development of professional networks (Table 4).

Among several separate models for each of the outcome variables, we chose to show the ones in which all the independent variables were significant. Model 1 tested the relationship of online interactions and motivation to learn. Both participant–content and participant–participant interactions had significant positive relationship with participants' motivation to learn ($b = 0.137$, $p < 0.05$; $b = 0.204$, $p < 0.05$, respectively). In addition, the results showed that week had a significant negative relationship ($b = -0.190$, $p < 0.001$) on participants' motivation. In another words, in the earlier weeks, participants were more likely to be motivated to learn. Additionally, time-rank had a significant positive relationship ($b = 0.073$, $p < 0.01$) to participants' motivation, suggesting that the later a participant posted on the course website in any one week, the more s/he was motivated to learn.

Model 2, which tested the relationship of online interactions with participants' intent to adapt environmental education ideas and practice, showed that participant–content interaction had a significant positive relationship ($b = 0.121$, $p < 0.05$) with participants' intent to adapt course ideas to their programs. Further, time-rank had a marginally significant positive relationship ($b = 0.039$, $p < 0.1$) to participants' intent to adapt, suggesting that the later a participant posted on the course website in any one week, the more s/he intended to adapt environmental education ideas. And work-year showed a marginally significant negative relationship ($b = -0.037$, $p < 0.1$) with participants' intent to adapt environmental education ideas, which suggested that less experienced participants were more likely to adapt environmental education ideas.

Model 3, which tested the relationship of online interactions with participants' adaptation of environmental education ideas and practice, showed that only participant–content interaction had a significant relationship ($b = 0.668$, $p < 0.001$) with adaptation. Only 8 quotes related to adaptation occurred across all 9 weeks, all of which were associated with course content. In addition, week had a significant positive relationship ($b = 0.268$, $p < 0.01$) on participants' adaptation of environmental

Table 4.   Relationships between interactions and outcomes.

Interactions: independent variable	Outcomes: dependent variable			
	Motivation Model 1	Intent to adapt Model 2	Adaptation Model 3	Network Model 4
Intercept	−1.270 (0.794)	−0.639# (0.335)	−7.622*** (1.100)	−3.749*** (0.635)
Participant–content interaction	0.137* (0.066)	0.121* (0.056)	0.668*** (0.163)	
Participant–participant interaction	0.204* (0.088)			0.298* (0.133)
Participant–instructor interaction				1.467* (0.612)
Week	− 0.190*** (0.050)		0.268** (0.097)	
Time-rank	0.073** (0.027)	0.039# (0.023)		
Work-year		− 0.037# (0.020)		
Number of observation	202	202	202	202

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; #$p < 0.1$.

education ideas. In another words, in the later weeks participants were more likely to adapt environmental education ideas into their practice.

Model 4 tested the relationship between online interactions and participants' intent to develop professional networks with other participants and instructors. Both participant–participant and participant–instructor interaction showed significant positive relationship with participants' intent to develop professional networks ($b = 0.298$, $p < 0.05$; $b = 1.467$, $p < 0.05$, respectively).

Discussion

As one of multiple professional development platforms provided through EECapacity, the *Environmental Education in Urban Communities* online course that was the focus of this study sought to foster innovative practices in environmental education through creating opportunities for educators holding different perspectives to share ideas and practices. Thus, in contrast to online learning evaluations in other contexts that have explored content mastery or adopting practices (Moore 1989), and consistent with interactive (Illeris 2007) or social learning approaches (Sol, Beers, and Wals 2013; Wals 2007), in this study we were most interested in networking and adapting practices through interactions with others. The results of this study add to past evaluations of online courses in environmental education professional development that focused on adopting practices, feeling more confident to teach, and course satisfaction (Cordie 2009; Dillard 2006; Lockman 2006; Wang 2007; Wilcox 2004).

Previous studies indicate that participant–instructor interaction has a positive relationship with participants' satisfaction (Andersen 2013) and achievement (Hong 2002), and their decisions to take a particular online course (Northrup 2002). In this study, interaction of course participants with the instructor was related to only one outcome: developing networks with other course participants. Although this result is perhaps counterintuitive, it is consistent with studies of online learning in other contexts that used social network analysis to examine course interactions, and found that instructors encouraged communication among participants (De Laat et al. 2007a, 2007b). This result may also be related to the instructor's pedagogical approach, which encouraged participants to learn from each other, in the hopes that this would lead to program innovations. Interaction of course participants with the instructor was not associated with intent to adapt or adaptation of environmental education ideas. Although instructors made comments on participants' assignment posts, it is possible that the instructors' comments were less useful in thinking about program adaptation than program content.

Not surprisingly, interaction with content was not associated with participant networking, but instead related to motivation, intent to adapt, and adaptation, indicating the importance of attention to content even in online courses where interactive or social learning is emphasized. The incorporation of multiple content formats, including videos and games, is also important to student course satisfaction (Northrup 2002).

Participant–participant interaction has been recognized as an important pedagogical approach in online courses and has a positive relationship with participants' content learning (Graham and Scarborough 2001; Jung et al. 2002; Moore 1989). In

this study, such interaction contributed to motivation to learn and professional networks but not to adaptation or intent to adapt practices, despite the fact that participants expressed significant interest in learning about their peers' programs in their weekly posts. This result runs counter to and thus suggests reexamining the guiding premise of EECapacity and of the *Environmental Education in Urban Communities* online course, i.e. innovations in environmental education arise through networking among educators. In addition to the possibility that innovations in environmental education do not arise through networking, explanations of this 'negative' result include that the interactions needed for change in practice must be of greater intensity and duration than those enabled by a single online course, as suggested by the significant positive relationship between week and adaptation, and the fact that although course participants were encouraged to share their experiences as environmental educators, not every participant shared every week, and it is likely that most participants did not read all others' posts and comments. It is also possible that because the course participants' environmental education programs focused on specific local issues and resources, participants were not able to transfer or apply what they learned from other educators to their own locations and educational settings. Finally, participant–participant interactions during the course, which were associated with motivation to learn and networking, may have provided a basis for further exchange of ideas that lead to practice innovation in the future.

Week, time-rank and work-year were associated with participants' motivation to learn, intent to adapt ideas, and adaptation of ideas. Previous studies used social network analysis to examine course interactions and found that the overall interactions among participants were denser in the beginning and middle compared to the end (De Laat et al. 2007a, 2007b). In our study, participants were more likely to be motivated to learn in the earlier weeks, perhaps because they were initially curious or excited about other participants' programs and course content. However, participants were more likely to intend to adapt environmental education ideas into their practice in the later weeks perhaps due to length of time needed for adaptation. In addition, the later participants posted on the website in any one week, the more they were motivated to learn and intended to adapt ideas. It could be that participants who posted earlier might not go back to read the later posts and thus had less chance to be impacted by other participants' posts. Finally, less experienced participants were more likely to intend to adapt environmental education ideas suggesting they were more open to new ideas.

This study is the first we are aware of that uses content analysis of course participants' online postings and generalized estimation equation models to address questions of interactions in online courses. Other studies of online courses used content analysis to examine participants' interaction but did not address outcomes (Gunawardena, Lowe, and Anderson 1997; Veldhuis-Diermanse 2002), or addressed outcomes using surveys of course participants, but did not focus on multiple types of interactions (Cordie 2009; Dillard 2006; Lockman 2006; Wang 2007; Wilcox 2004). Whereas using content analysis is timing consuming, it does enable us to gather more objective and richer evidence of learning than might be possible through surveys with close-ended questions. Further, it provides data that can be analyzed quantitatively with modeling, while still shedding light on the processes by which outcomes may occur.

Limitations

The fact that this study focused on only one online course limits our ability to make generalizations about online learning. Further, we did not separate out any effects of the type of course content (e.g. video and reading) or of the quality of the interactions or outcomes. In addition, adaptation and development of networks take time. Although we distinguished adaptation and intent to adapt during the course, we did not conduct a follow-up survey several months after the course to measure consequent adaptation and networking. Finally, we were only able to report correlations among interactions and outcomes rather than any causal relationships. These shortcomings could be addressed through studies in which the type of interaction is varied, and through conducting future and synthesizing existing studies of online learning in a diversity of contexts.

Applications and conclusion

Our findings demonstrate that different types of participant interactions – with course content, other participants, and instructors – are associated with different outcomes for professional educators. Thus, the findings suggest that online course developers may use different types of interactions in designing the learning experience, including interactions among participants, which may motivate other participants and foster professional networks. This study also suggests the possibility of promoting particular course goals through unexpected means, for example, focusing on the role of the instructor in facilitating networking among students. The result that interaction with content was most likely to be associated with intent to adapt and actual adaptation of practice, whereas interaction with other participants was not associated with this outcome, suggests the importance of content in fostering innovation even in courses that emphasize participant interactions. Given that participant–participant interactions were associated with networking, which in other studies has led to innovation, one possibility would be to provide social media and other platforms for course participants to continue their interactions after a particular course has ended, and to determine whether such longer term participant interactions lead to innovation.

In sum, for program designers, the results of this study suggest the need to pay particular attention to course elements that foster interactions consistent with professional development goals – whether they be focused on personal, professional, and social development (Bell and Gilbert 1996). Additionally, given that online courses are of limited duration and educators need ongoing support to implement changes in practice (Penuel and Means 2004), attention should be paid to how an online course fits into a suite of long-term web-mediated and other professional development opportunities. For researchers, the results suggest more rigorous examination of social innovation theory's focus on creating 'trading zones' whereby educators can exchange ideas as a means to foster innovation (Krasny and Dillon 2013). For example, what kinds and what duration of interactions lead to innovation? How do educators transfer ideas from one practice to another? And how do interactions with other educators and instructors interact with program content in fostering innovation?

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Notes on contributors

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