Moving Ahead in the Study of STEM Interests and Interest Development: A New Research Agenda

Flávio S. Azevedo (chair), The University of Texas at Austin, flavio@austin.utexas.edu
June Ahn, University of Maryland, College Park, juneahn@umd.edu
Michele J. Mann, The University of Texas at Austin, mjmann@utexas.edu
Rena Dorph, The Lawrence Hall of Science, University of California, Berkeley, rdorph@berkeley.edu
Matthew A. Cannady, The Lawrence Hall of Science, University of California, Berkeley, mcannady@berkeley.edu
Victor R. Lee, Utah State University, Logan, vrlee@usu.edu
Ryan Cain, Utah State University, Logan, ryan.cain@aggiemail.usu.edu

Philip Bell (discussant), University of Washington, Seattle, pbell@u.washington.edu

Abstract: We seek to jumpstart a program whose long-term goal is to advance a more nuanced and encompassing understanding of STEM interests by comparing and contrasting how they are manifested across settings of STEM practice. People can and do get interested in STEM-based activities in the various spaces in which they encounter these activities—e.g., the home, museums, hobby fields, school, and after-school programs. However, because each such setting operates under different constraints and affordances, the forms of interest-based participation they spawn and support are qualitatively different. This symposium brings together four distinct research projects, each of which addresses very different settings, aspects, and phenomena in people's interest-based participation in STEM. The projects also deploy very different methodologies to document and measure people's interests. By comparing and contrasting these very distinct takes on interests and their manifestations across settings, we gain insight into both generalities and context specific aspects of interests and their enactment.

Symposium goals

Heeding ICLS 2016's focus on "Transforming learning, empowering learners… to design their social futures," this symposium addresses central, yet little understood aspects of learning processes—namely, the functioning of interests and their development over time, especially in and around STEM domains and disciplines (e.g., Renninger, Nieswandt, & Hidi, 2015). Short- and long-term interests have long been recognized as essential factors mediating how, when and what one learns in an activity (Dewey, 1913; Krapp, Hidi, & Renninger, 1992). The centrality of interests for learning processes is further foregrounded when we consider the lifelong and lifewide character of learning (National Research Council, 2009). Empowering learners must therefore include mechanisms to support them in the earnest pursuit of their interests, emergent and long standing.

For historical, practical, and methodological reasons, however, progress in the field has been slow to obtain—say, relative to advances in theorizing discipline-specific learning processes (e.g., Smith, diSessa, & Roschelle, 1993/1994) or the socio-cultural foundations of learning (e.g., Lave & Wenger, 1991). In particular, we note that the nearly exclusive focus on interest-based learning and phenomena in classroom contexts has produced theorizing that lacks generality and texture—a point made by Weiner (1990) more than two decades ago. To be sure, we have progressed much since then, but we contend that a more expansive and inclusive research agenda could offer new theoretical, methodological, and practical insights onto interest-related phenomena and spur renewed investigation in the field. For example, recent research in the learning and cognitive sciences has shown that interest-based participation may take on a very different character across contexts and timescales of practice (e.g., Barron, 2006; Bricker & Bell, 2014; Lee & Drake, 2013)—phenomena still not well understood or documented.

Based on these observations, this symposium seeks to jumpstart a program whose long-term goal is to advance a more nuanced and encompassing understanding of STEM interests by *comparing and contrasting how they are manifested across settings of STEM practice*. Building on the collective insights of the literature, we know that people can and do get interested in STEM-based activities in the different settings (e.g., the home, museums, hobby fields, school, and after-school programs) in which they encounter these activities (NRC, 2009). However, because each respective setting operates under different constraints and affordances (e.g., institutional, material/infrastructural, and time demands), the forms of interest-based participation they spawn and support must differ at some fundamental level. Put differently, STEM interests are expressed in *qualitatively different forms* depending on the settings and practices in which they are embedded. By comparing and contrasting different "versions" or manifestations of interests (and related phenomena) across such settings, therefore, we gain insight into both generalities and context specific aspects of interests and their enactment. Our central goal here is to illustrate this approach, as we explain next.

Goals and structure, elaborated

In line with the arguments above, this symposium brings together four distinct research projects, each of which addresses very different aspects of people's interest-based engagement in STEM. The individual projects investigate a broad range of STEM practices and learning settings—specifically, and in order of presentation, an all-girls STEM-centered after-school Maker program, the fields of amateur astronomy, school-based STEM activities, and a large-scale, alternate reality game (ARG) that was played across a variety of online and social media platforms. By explicitly drawing on this diversity of settings, we seek to illuminate dimensions and phenomena of interest-based participation that might otherwise stay hidden (e.g., in institutional, disciplinary, and other structural arrangements) and to bring new light on the relationship among these phenomena.

Fittingly, the individual presentations also deploy widely different methodological strategies to gain access to, and to analyze the interest-based phenomena under study. These methodologies include long-term ethnographies, assessments and scale development, and descriptive analytics of trace data from digital gameplay, among others. This methodological plurality further informs us about the diversity of interest-related phenomena and the equally diverse ways of capturing those. Grounding the symposium, each presentation will explicitly highlight interest-related phenomena—observed or otherwise inferred, through various methods—that "appears" in their data. Taking these as departure points, Dr. Phil Bell, our discussant, will then begin (1) the task of comparing and contrasting these phenomena and broader results, and (2) highlight areas of intersecting and diverging results, thus revealing interests' versions/manifestations across contexts. In doing so, Dr. Bell will also bring in his own extensive work on various settings of out-of-school STEM learning and the forms of engaged participation they foster. This will set the frame for audience participation and questioning.

Wearing their feelings on their sleeves? Wearable technology and the capture of student engagement with Maker activities

Victor R. Lee and Ryan Cain, Utah State University

Project description

The goal for this project, in partnership with a youth-focused community makerspace, has been to interrogate the popular assertion that participation in "Maker" activities establishes "interest in STEM, the arts, and learning as a whole" (Dougherty, 2013, p. 14). Capitalizing on some of our existing awareness of new wearable technologies that can be productively used to support and study learning environments (Lee, 2015), we sought to leverage these new technologies to help us capture and characterize conditions that trigger interest and associated phenomenology of high student engagement in Maker activities. While interest and engagement are different, albeit related constructs, we focus on engagement as the observable indicator of interest, as it can be determined using psychophysiological measurement of electrodermal activity (EDA).

Theoretical framework

This study is informed by both Hidi & Renninger's four-phase model of interest development (2006) and by a growing body of learning sciences research on interest that has highlighted complexities of how interests are manifested *in situ* when participating in out-of-school discretionary activities (Azevedo, 2011; Barron, 2006). With respect to the former, we are concerned with the initial moments of triggered situational interest (Phase 1) that are thought to serve as a basis for the development of a sustained and well-developed individual interest (Phase 4). From the latter, we seek to be attentive to the diversity of possible manifestations of interest that could emerge among multiple individuals in the same environment and under similar material conditions. In terms of Maker practice, this means that we may expect some activities can be broadly interesting for a group of youth because they are novel and promote engagement. At the same time, we do not expect all triggers to be the same for all students. As we discuss below, dramatic changes in setting can be generally engaging for multiple students. On the other hand, opportunities to use new technologies may trigger engagement for some, as is the case for one student who was more engaged with her own sensor testing while her partner had different triggers.

Methods

We have been using two new wearable technologies: EDA bracelets and wearable still-image cameras (Figure 1). The EDA bracelets, Affectiva Q sensors, are wearables that send electricity between two contacts on the wearer's skin and detects changes in EDA. Initial research on their use suggests they can capture changes in conductance that correlate well with those accepted as among the best in psychophysiological research (Poh, Swenson, & Picard, 2010) but allow the wearer to be mobile and active. The cameras are Autographer wearable cameras, which automatically capture multiple still images each minute from the wearers' point of view. These devices were provided to four adolescent girls participating in a 15-week atmospheric science-themed afterschool maker camp, who wore both devices throughout each camp session.

We note in our presentation there are some inherent challenges with relying too heavily on data from wearables. Namely, changes in EDA reflect changes in arousal, which is associated with increased attention and emotional engagement, but can be positive or negatively valenced. Additionally, parsing EDA data is challenging in that it requires a substantial amount of manipulation as 160 data points are created per minute and base skin conductance naturally changes gradually over time. Also, EDA is typically measured in controlled lab settings where relationships between stimuli and EDA can be directly tested. We have been developing algorithms to help detect when there has been a clear change in arousal and then seeking regularities in actions depicted in the still images given the known challenges. These challenges we consider insurmountable, and the potential payoff of capturing individual and group interest in situ makes this worth exploring. We have obtained third-person video of each session to help us verify and triangulate inferences from the wearables.

Figure 1. The combination of time-stamped wearable still-image and EDA data sets enable the capture of youths' perspective of what they are seeing and doing that has triggered immediate engagement.

Results and implications

To date, we have begun to see instances of regularities of triggers among youth and have amassed evidence of activities and experiences in Maker spaces that yield high and low levels of arousal. For instance, two girls who worked together on assembling a sensor both seemed to exhibit high arousal each time they were asked to change physical settings. Yet there appeared to be moments that were more uniquely engaging to one student rather than the other. One of the two girls appeared to have increases in engagement each time she was testing her assembled sensor. As a contrast, this same girl also had lower level of engagements when running information searches on one of the Makerspace-provided laptops. In our presentation, we will discuss what findings like these suggest to us about engagement in Makerspaces across and within individuals and how these methods could give us some headway to understanding interest dynamics in such a complex physical setting.

The role of fascination and values in developing science career interest

Rena Dorph and Matthew A. Cannady, The Lawrence Hall of Science, University of California, Berkeley

Project description

The purpose of this presentation is to explore the degree to which learners who are fascinated by natural and physical phenomena and/or value science in everyday contexts are more likely to identify these areas as a possible career fields while in their middle school years. We will explore the role of each these constructs separately as well as how they may interact in order to understand if either of them are more influential drivers of science or engineering career interest.

Theoretical framework

Fascination with natural and physical phenomenon refers to the emotional and cognitive attachment/obsession that the learner can have with science topics and tasks that serve as an intrinsic motivator towards various forms of participation. This dimension includes aspects of what many researchers have referred to as curiosity (Litman & Spielberger, 2003), interest or intrinsic value in science both in and out of school (Hidi & Renninger, 2006; Osborne, Simon, & Collins, 2003; Hulleman & Harackiewicz, 2009), and mastery goals for science content (Ames, 1992). It also includes positive approach emotions related to science, scientific inquiry, and knowledge. Past research has found that each of these constructs to be associated with choice towards, engagement during, and attainment in science learning (Hidi & Renninger, 2006; Hidi & Ainley, 2008). As a whole, we hypothesize that fascination is an important driver towards career interest.

Valuing science refers to the degree to which learners value the knowledge learned in science, the ways of reasoning used in science, and the role that science plays in families and communities. In addition, in a young person, valuing science may express itself as both everyday value and career value (Hill & Tyson, 2009). A learner can understand various interactions of self with science knowledge and skills and places value on those interactions within their social context (Eccles & Wigfield, 2002; Osborne, Simon, & Collins, 2003). Those who value science and the role it plays—both in their own lives and in society—are more likely to engage in learning science in and out of school whether or not they find it fascinating (Eccles, 2005; Lyons, 2006). Hence, like fascination, valuing science is also an important motivator towards success in science learning and science careers.

Methods

The analysis draws upon both qualitative and quantitative data sources collected as part of the research efforts of the *Activation Lab* (www.activationlab.org). Interviews about science fascination, value and career interest with 16 middle school students were analyzed to understand the degree to which young people's thinking about career interest is related to their fascination with natural and physical phenomena and the value they place on the scientific enterprise. In addition, analyses of survey data (fascination scale, values scale, and STEM career interest items) collected from a longitudinal study of over 1,500 6th and 8th graders drawn from multiple, diverse schools within two regions in the US was conducted. In particular, we examined models predicting growth in each construct and the relationship that growth had with changes in career interest.

Results and implications

Data analysis revealed that both fascination and everyday valuing of science are related to STEM career interest in middle school-aged youth. Observations of, and interviews with, youth participating in school-based science learning environments reveal that youth who indicate interest in a science-related career are also more likely to either express fascination with the natural or physical world and/or to clearly articulate the value of science for society. Examples of the ways youth express fascination include: expressing interest for particular science ideas or activities exclaiming how "awesome" a particular activity is. Examples of how youth articulate "valuing science" include expressing the role that science plays in improving people's lives through "inventing things that help people," "discovering cures for diseases," and "solving important problems."

Next, we note that survey measures of both fascination or valuing science and career interest are significantly correlated to one another above and beyond relationships with demographics, science competency beliefs, or other variables of interest. Further analysis is underway to reveal how fascination and values interact, to understand if either of them are most influential as a driver of career interest, and to learn for whom and under what conditions each of these constructs is a more influential driver of career interest.

Further, we find that youth across a variety of learning environments (school-based, summer camps, after-school, etc.) who report higher levels of fascination and valuing of science (i.e., science writ large, not a specific domain) have higher levels of engagement in their specific science learning environment. That is, being fascinated and valuing science as a subject seems to position youth to be more likely to engage in a science learning environment regardless of setting (formal vs. informal) and specific science content. We thus see the support that fascination and valuing of science provides manifest in the ways youth build and rely upon a science identity and personal engagement in science learning activities.

The interest-centered pedagogy of amateur astronomy practice

Flávio S. Azevedo and Michele J. Mann, The University of Texas at Austin

Project description

Hobbies are widely seen as prototypically interest-driven practices (Krapp, Hidi & Renninger, 1992; diSessa, 2000), and studying how they structure teaching and learning opportunities can provide us many lessons regarding the nature of interests and how we might effectively design for truly interest-driven engagement. We focus on the practice of amateur astronomy as empirical ground and rely on long-term ethnographies of astronomy practice to capture the richness of interest-based participation and its phenomenology, and the learning that takes place in it.

Analytically, we approach this material from the perspective of *pedagogy* and investigate how teaching/learning events seem to be systematically structured in the hobby, across short and long term pursuits. To be sure, there are many competing models and definitions of pedagogy. Our larger goal is to contribute to this debate by mapping out the essential aspects of the pedagogy of amateur astronomy practice and thus to begin illustrating what pedagogies for interest development might look like. In the spirit of the symposium, we will link these issues directly to the phenomenology of interest-driven participation observed in the hobby.

Theoretical framework

The theoretical framework guiding our inquiry has two major components. First, we draw on *lines of practice* theory (Azevedo, 2011, 2013) to frame how we look for aspects of pedagogy in a hobbyist's pursuit of the practice (amateur astronomy, in this case). A line of practice describes a specific set of medium- to long-term activities in a person's pursuit of a practice of interest. Any practitioner pursues multiple parallel lines of practice, each of which reflecting a person's unique *preferences* in the practice, and preferences are continuously attuned to the *conditions of practice* imping on one's hobby (e.g., access to resources such as literature, telescopes, sites of practice, and more competent peers). The point to observe is that practitioners learn along their tailored lines of practice and therefore following these processes of learning shed light on the phenomenology of interests and their pedagogical significance.

The second major component of our framework regards a particular lens into the nature of socio-cultural practices and their organization, and a consequent understanding of when and how teaching/learning occurs. Traditionally, we have associated learning with direct acts of teaching. Given the interest-based nature of hobbies, however, we decouple learning from teaching (Lave & Wenger, 1991; Stevens, 2000) in order to: (1) allow for the possibility of a pedagogy of (partially) self-teaching, which is ubiquitous in amateur astronomy (and other hobbies); and (2) to capture the fluid arrangements of teaching and learning that happened at short timescales of collaborative field practice.

Methods

We draw from two different studies, both long-term ethnographies (Hammersley & Atkinson, 1995) of amateur astronomy communities, spanning a total of 3 communities/clubs and several individual astronomers as cases studies. The first study was carried out by the first author between the years of 2002 and 2003 and it included two communities in Northern California. Briefly, the study sought to capture practitioners' patterns of long-term, interest-based participation and how these emerged in the interactions between practitioners and the larger spaces of practice that they frequented. In the second study, throughout the year of 2014 we followed a community of amateur astronomers who met regularly at the High Meadows site in the Texas hill country. This time we were specifically concerned with documenting teaching and learning events and how they came about, and particularly how embodied cognitive practice played out in observational amateur astronomy. Overall, we collected more than 15 hours of videotapes and several pages of field notes and analytical and theoretical memos.

Results and implications

In presenting our results, we comb through our ethnographic records in search of teaching and learning interactions—across a range of timescales—and list their associated phenomenology. For each of these, we then draw inferences regarding the explicit or implicit aspects of pedagogy involved:

1. Phenomenology: Participating in peers' activities. During collective field practice, it is not uncommon for an astronomer to be "absorbed into" other participants' own observational goals and activities.

   Pedagogy: Unintended, serendipitous learning/teaching of content that prepares for future pursuits; interactions strengthen relationships. Occasional encounters with astronomy practices (say, in a visit to a museum) lead to similar results.
2. Phenomenology: Reading at home and explicitly formulating learning goals.

   Pedagogy: While learning goals are prominent in amateur astronomy, they are not the sole or even most important goal that practitioners nurture. Still, astronomers routinely engage in self-teaching by reading various specialized literature.
3. Phenomenology: Fluid switching of teaching roles. In the common collaborative pursuits that emerge in field practice, relative novices routinely teach some content to more experienced peers.

   Pedagogy: Legitimate peripheral participation (Lave & Wenger, 1991).
4. Phenomenology: Pursuing themed observational lists. Organized, themed lists of observational target are deeply shared within and across amateur astronomy communities (and indeed the hobby as a whole).

   Pedagogy: Lists constitute the emergent and more stable curricula that serve to structure long-term, self-paced, interest-based engagement.

As we advance in our analysis, we will add many more elements to this list and thereby increase the space for cross-comparisons analyses of setting-specific interest-based participation.

Fascination, self-competency beliefs, and expressions of play in an alternate reality game

June Ahn, University of Maryland, College Park

Project description

Alternate reality games (ARGs) ask players to assume roles as characters in an interactive fiction. ARGs are played across multiple platforms with puzzles and activities that are distributed across social media, books, video, and real world environments (Bonsignore et al., 2012, 2013). Our research team has been designing and researching the potential for ARGs to promote informal science learning for youth. Our first ARG called DUST, in collaboration with NASA, launched in January 2015 and garnered over 2,000 registered players. The story of DUST revolved around a group of diverse teenagers, who witness a meteor shower at a NASA facility. All of a sudden, the adults collapse, unconscious, and it is up to the teenagers of the world to solve the mystery and save humankind. The story is told over time, through graphic novels, and teen players utilize online platforms to pose questions, theories, evidence, and notebook reflections (QTEN) to collaboratively research and solve the mystery. We detail the complex design challenges of DUST to authentically integrate scientific inquiry with gameplay (Pellicone et al., forthcoming). Furthermore, our emerging work attempts to take log data from DUST platforms, and use various data analytics to understand players' choices for play within the designed environment of the ARG.

Theoretical framework

Azevedo's (2011, 2013) work on *lines of practice* inform our exploration into interests and its expression in designed game experiences such as ARGs. First, it is important to know that learners come to a given learning experience with existing *preferences* for practice and sense of self. We focus on two concepts – fascination and self-competency beliefs – that may characterize one's preferences for practice (Crowley, Barron, Knutson, & Martin, 2015; See Dorph and Cannady in this session). To engage in a practice, one must have some level of fascination about some aspect of the activity and also have some level of belief that they can participate in the activity. In DUST, players bring different levels of fascination and self-beliefs about their ability to engage in the scientific inquiry practices that comprise the ARG.

Second, the features of a material environment may allow or constrain the expression of these preferences, and through activity, further deepen these lines of practice over time. Thus, players' fascination and self-competency beliefs may then intersect with the kinds of activities that were explicitly designed in the ARG. For example, in DUST players had to forward the interactive narrative by posing questions, forming theories, and finding and arguing for their theories with evidence. Players could also do a variety of other activities including network with friends, collaborate on tasks, and discuss ideas. Taken together, we aim to examine whether and how prior levels of fascination and self-competency beliefs relate to the diverse ways that players can appropriate the different designed-experiences in an ARG.

Methods

DUST was an entirely open, informal experience. Through various recruitment efforts, over 2,000 players joined DUST. When players registered, we collected demographic data along with measures of fascination and self-competency beliefs in science (see Dorph & Cannady, this session). The various online platforms that players used to debate their QTEN contributions also were instrumented to record detailed, time-stamped logs of player activity. This data collection effort motivates various analytic strategies to better understand how learners came to, and experienced DUST, over time. We will present two facets of our preliminary and emerging work (1) our efforts to construct variables of game activity from log data and (2) how these measure of activity relate to learners' fascination and self-competency beliefs in science.

Results and implications

In this presentation, we will present our initial data analysis on player demographics of our teenage players (n=1,027), and descriptive analysis of the fascination and self-competency belief measures. We also began constructing measures of game activity, thinking about the designed affordances of DUST. For example, we created counts of the core QTEN activities that were integral to creating the interactive narrative in DUST. Players could also network and "friend" other players in the game, which allowed us to create social network graphs and counts of how many others a player was connected to. We will present various visualization techniques used to explore the data to understand how individual players contributed QTEN posts.

In addition, we explore the relationship between fascination and self-competency beliefs with these patterns of contribution (Table 1), which begins to illuminate new avenues for inquiry. For example, fascination and competency beliefs were correlated with all types of QTEN activity but not friendship activity. In addition, there are intriguing relationships for further exploration between types of contributions. For example, in our qualitative data and interviews with players, we found that some players who did not feel confident enough to contribute QTE's – perhaps feeling that these were high-barrier scientific practices requiring expertise – often stated that they preferred instead to post free-form "notebook" posts. However, we saw in our data that posting of notebook posts was also correlated with posting questions, theories, and evidence. Could certain modes of game contribution, say notebook posting, appeal to certain players (e.g., who feel less competent in science to begin), but be a gateway to other expressions such as engaging in theorizing, questioning, and arguing from evidence? Building from these preliminary examples, we will present various ways to use analytics to better understand these relationships between facets of interest and the developing expressions of players' game activities through the designed affordances of DUST.

Table 1: Correlations between Activation Scales, Friends, and QTEN contributions

	Fascination	Self-Competency	Friends	Question	Theory	Evidence	Notebook
Fascination	1.0						
Self-Competency	0.69*	1.0					
Friends	-0.07	-0.06	1.0				
Question	0.23*	0.14*	0.20*	1.0			
Theory	0.23*	0.20*	0.20*	0.57*	1.0		
Evidence	0.16*	0.15*	0.35*	0.57*	0.53*	1.0	
Notebook	0.15*	0.13*	0.31*	0.22*	0.33*	0.38*	1.0

* $p < 0.05$

References

Ames, C. (1992). Classrooms: Goals, structures and student motivation. *Journal of Educational Psychology*, *84*(3), 261-271.

Azevedo, F. S. (2011). Lines of practice: A practice-centered theory of interest relationships. *Cognition & Instruction, 29*(2), 147-184.

Azevedo, F. S. (2013). The tailored practice of hobbies and its implication for the design of interest-driven learning environments. *Journal of the Learning Sciences*, *22*(3), 462–510.

Barron, B. (2006). Interest and Self-Sustained Learning as Catalysts of Development: A Learning Ecology Perspective. *Human Development, 49*(4), 193-224.

Bonsignore, E., Hansen, D., Kraus, K., Ahn, J., Visconti, A., Fraistat, A., & Druin, A. (2012). Alternate Reality Games: platforms for collaborative learning. In *Proceedings of the 10th International Conference of the Learning Sciences*.

Bonsignore, E., Hansen, D., Kraus, K., Visconti, A., Ahn, J., & Druin, A. (2013). Playing for Real: Designing Alternate Reality Games for Teenagers in Learning Contexts. In *Proceedings of the 12th International Conference on Interaction Design and Children* (pp. 237–246). New York, NY: ACM.

Bricker, L. & Bell, P. (2014). "What comes to mind when you think of science? The perfumery!": Documenting science-related cultural learning pathways across contexts and timescales. *Journal of Research in Science Teaching*, *51*(3), 260-285.

Crowley, K., Barron, B. J., Knutson, K., & Martin, C. K. (2015). Interest and the development of pathways to science. *Handbook of Iinterest in Mathematics and Science Learning and Related Activitiyes. Washington, DC: AERA*.

Dewey, 1913. Dewey, J. (1913). *Interest and effort in education*. Boston, MA: Riverside Press.

diSessa, A. A. (2000). *Changing minds: Computers, learning and literacy*. Cambridge, MA: MIT Press.

Dougherty, D. (2013). The maker mindset. In M. Honey & D. Kanter (Eds.), *Design, Make, Play: Growing the Next Generation of STEM Innovators* (pp. 7-11). New York, NY: Taylor & Francis.

Eccles, J. S. (2005). Subjective task value and the Eccles et al. model of achievement-related choices. *Handbook of competence and motivation*, 105-121.

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual review of psychology.* 53:109-32.

Hammersley, M. and Atkinson, P. (1995). *Ethnography principles in practice.* London: Routledge.
Hidi, S., & Ainley, M. (2008). Interest and self-regulation: Relationships between two variables that influence learning. In D. H. Schunk & B. J. Zimmerman (Eds.), *Motivation and self-regulated learning: Theory, research, and applications* (pp. 77-109). Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers.
Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 41*, 111–127.
Hill, N. E., & Tyson, D. F. (2009). Parental involvement in middle school: a meta-analytic assessment of the strategies that promote achievement. *Developmental Psychology, 45*(3), 740.
Hulleman, C. S., & Harackiewicz, J. M. (2009). Promoting interest and performance in high school science classes. *Science, 326*(5958), 1410-1412.
Krapp, A., Hidi, S., & Renninger, K. A. (1992). Interest, learning, and development. In K. A. Renninger, S. Hidi, & A. Krapp (Eds.), *The role of interest in learning and development,* (pp. 3-25). Hillsdale, NJ: Lawrence Erlbaum Associates.
Lave, J. & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.
Lee, V. R. (Ed.) (2015). *Learning technologies and the body: Integration and implementation in formal and informal learning environments.* New York, NY: Routledge.
Lee, V. R., & Drake, J. (2013). Digital physical activity data collection and use by endurance runners and distance cyclists. *Technology, Knowledge and Learning, 18*(1-2), 39-63.
Litman, J. A., & Spielberger, C. D. (2003). Measuring epistemic curiosity and its diversive and specific components. *Journal of Personality Assessment, 80,* 75-86.
Lyons, T. (2006). Different countries, same science classes: Students' experiences of school science in their own words. *International Journal of Science Education, 28*(6), 591-613.
Martin, T., & Sherin, B. (2013). Learning Analytics and Computational Techniques for Detecting and Evaluating Patterns in Learning: An Introduction to the Special Issue. *Journal of the Learning Sciences*, *22*(4), 511–520. http://doi.org/10.1080/10508406.2013.840466
National Research Council (2009). *Learning science in informal environments: People, places, and pursuits*. Committee on Learning Science in Informal Environments. P. Bell, B. Lewenstein, A. W. Shouse, and M. A. Feder (Eds.). Board of Science Education, Center for Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academy Press.
Osborne, J. F., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079.
Pellicone, A., Bonsignore, E., Kaczmarek, K., Kraus, K., Ahn, J., & Hansen, D. (forthcoming). Alternate reality games for learning: A frame by frame analysis. In A. Garcia & G. Niemeyer (Eds.), *Alternate Reality Games and the Cusp of Digital Gameplay*. New York, NY: Bloomsbury.
Poh, M.-Z., Swenson, N. C., & Picard, R. W. (2010). A wearable sensor for unobtrusive, long-term assessment of electrodermal activity. *IEEE Transactions on Biomedical Engineering, 57*(5), 1243-1252.
Renninger, K. A., Nieswandt, M., & Hidi, S. (2015). *Interest in mathematics and science learning*. Washington, DC: AERA Press.
Smith, J. P., diSessa, A., and Roschelle, J. (1993/1994). Misconceptions reconceived: A constructivist analysis of knowledge in transition, *Journal of the Learning Sciences*, *3*(2), 115-163.
Squire, K. (2006). From Content to Context: Videogames as Designed Experience. *Educational Researcher*, *35*(8), 19.
Stevens, R. R. (2000). Divisions of labor in school and in the workplace: Comparing computer and paper-supported activities across setting. *Journal of the Learning Sciences*, *9*(4), 373-401.

