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Affective Learning in Playful Learning Environments: Physics Outreach Challenges

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Abstract

This field report describes the affective learning experiences of students as they participate in two physics outreach challenges: the Physics Olympics and BC's Brightest Minds amusement park physics competition. Students were interviewed before and after the events and observed closely while they participated, with particular attention paid to the emotions they expressed. The researcher used a complexity thinking perspective to interpret how emotions allow for the emergence of perceived student science identities, which were adaptive and dynamic. Key findings include that experiencing strong emotions such as excitement and disappointment can enhance motivation and learning, and characteristics of the contexts and tasks that promote playful learning were identified. The results of this study contribute to improving the teaching and learning of physics and suggest designing learning environments both within and outside classroom contexts that are challenging and provide feedback so that students' emotions are evoked and expressed. Specific recommendations for designing competitive science outreach environments are also offered.

Keywords: *affective learning, complexity thinking, science outreach programs, physics*

Introduction

Build a musical instrument entirely out of food and use it to play “Twinkle, Twinkle, Little Star.” Determine the height, speed, and acceleration of a roller coaster using only simple tools such as a measuring tape and stopwatch. Design a homemade multimeter to measure voltage and resistance. These challenges sound formidable and they are meant to be. They are examples of activities in two high school physics outreach challenges in British Columbia (BC), Canada. However, these kinds of challenges achieve more than recognizing and rewarding top students, they are engaging, memorable and playful learning environments that can elicit strong emotions and change how students think about physics.

This field report will describe two novel physics outreach challenges, Physics Olympics (Riban 2000) and BC’s Brightest Minds amusement park physics competition (Moll 2010). These kinds of environments are particularly rich sites for investigating the role emotions play in science learning since students participate in teams in hands-on challenging activities where they experience success and failure, and express strong raw emotions such as joy, excitement, and frustration in the process. Thus, this report will also include the results of a study of the affective learning these learning environments can afford, particularly their potential for eliciting raw emotions, allowing for the development of science identities and influencing student attitudes towards science.

Playful Learning Environments: Physics Outreach Challenges

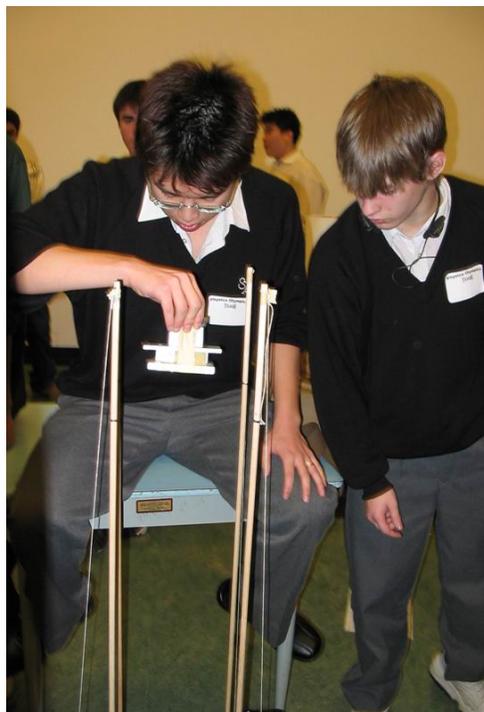
Science outreach programs can be particularly rich playful and emotional informal learning environments. They are primarily geared towards high-school students who are deciding what to study in post-secondary education. A large body of research points to the importance of attitudes towards science in student motivation, decision making, and learning about science in informal learning contexts (e.g. Rennie and Johnston 2004).

Informal learning contexts and learning via play have commonalities. Play is usually defined as voluntary and intrinsically motivating with a level of active and physical engagement (Rieber 1996). Play is distinct from other behaviors in that it usually encompasses a make-believe or other-worldly aspect. In the context of physics outreach challenges, students have the opportunity to take risks, experiment, and be creative outside of the constraints of the curriculum of their physics courses. Very little research has examined the similarities between learning opportunities in physics and play activities. However, one study found that adult physicists identified asking and answering questions about the world around them through childhood play with simple materials to be a fundamental experience that shaped their physicist identity (Hasse 2008). Physics outreach challenges can be described as playful environments for learning physics. The current study sought to specifically examine the affective learning that occurs in two popular physics outreach events, the Physics Olympics and BC’s Brightest Minds competitions.

The Physics Olympics is organized by the Department of Physics and Astronomy at the University of British Columbia (UBC) (<http://www.phas.ubc.ca/physoly/>). Participation in the event is a voluntary extracurricular activity for students. During

the competition, teams of five Grade 11 and 12 students from high schools across the province of British Columbia compete in six tasks, including quiz shows based on physics questions and trivia, laboratory or hands-on challenges, conceptual challenges, and tests of their two pre-built designs they prepare before the competition (see Figure 1). The event is attended by about 60 teams and occurs each year on the first Saturday in March. The teams are divided into groups of ten that cycle through the six tasks throughout the day. Results are tallied and at the end of the day the entire crowd (teams, coaches, parents, organizers and spectators) converge in a large lecture hall for a short physics show, door prizes and the announcement of the results. The top six teams in each task are recognized with medals for the top three, and finally the overall top three teams are announced and awarded trophies. No monetary awards are given but the University of British Columbia values participation and achievement in the Physics Olympics when considering students for admittance and entrance scholarships.

Figure 1. Students participating in a Physics Olympics event test the strength of their pre-built design: a structure that will protect an egg from a falling weight (author photograph)



The second event that was part of this study, BC's Brightest Minds, is organized by the Faculty of Education at UBC and staff from a local amusement park, Playland at the Pacific National Exhibition in Vancouver, BC (see Figure 2). It is an annual one-day event in May that has been running since 2006. The competition takes place on site at the amusement park on the same day as the regular amusement park physics program. The regular amusement park physics program is attended by classes of high school physics students from across the province. The program involves a one day visit to the amusement park to ride the rides and complete

worksheets with questions about specific rides which are designed to match curriculum expectations for high school physics courses. The competition extends the kinds of activities students complete during the regular program by having more challenging questions and limiting the amount of time they have to work on the question set. Teachers often make regular amusement park physics activities a required element of their course, however the competition is voluntary and does not count towards course credit. High schools are invited to nominate a team consisting of two Grade 12 students to participate in the competition; typically about 25 teams enter each year. The competition asks students to use simple tools to take measurements and observations of rides and perform calculations. Students are given three hours to complete the questions and during the event they have the opportunity to experience the rides and to collect data. Participating students receive free T-shirts and the top three teams are recognized, with the top team sharing a \$3,000 prize. The event receives quite a bit of media attention in the local community and winning students are often interviewed by local newspapers.

Figure 2. A pair of students calculate the height and speed attained during a roller coaster ride at the BC's Brightest Minds amusement park physics competition (photograph courtesy of Playland at the PNE)



The Physics Olympics competition has been described in the literature (Riban 2000). Escobar (1990) and McGehee (1988) have written about the benefits of participating in an amusement park physics program and provide useful background in both the physics of rides and methods for creating a rich learning experience from a school field trip to an amusement park. The power of the amusement park environment for affective learning has been recognized as Escobar (1990, 450) writes:

The experience reinforces what they have learned in class, brings up new questions, counters the prevailing myth that physics is abstract... and, best of

all, integrates enjoyment and intellectual activity. Physics in the amusement park is simple, it's real and it's fun.

However, the nature of the affective learning that occurs in these learning environments has not been the subject of close study.

Affective Learning Constructs: Emotions, Science Identity and Attitudes

The current study examines three affective learning constructs: raw emotions, science identity and attitudes towards science. While learning in science is usually studied from a cognitive perspective, the affective construct of attitudes towards science has also been widely studied. Student attitudes towards science typically decline as students progress in school (e.g., Yager and Penick 1986) and in a survey of the literature, Osborne, Simon and Collins (2003) concluded that attitudes are only moderately correlated to academic achievement. The affective construct of science identity has been used as a powerful lens through which student attitudes, motivations and decision making about science can be understood; usually this is approached from a situated learning perspective (Carlone 2003; Nespor 1994; Roth and Tobin 2007) which leaves little space for examining the role emotions play in the construction of science identities. In fact the study of raw emotions such as fear and happiness is often neglected (dos Santos and Mortimer 2003). Roth and Tobin (2007) recognized that science identities shift along an emotional spectrum and that the array of responses individuals can have during learning experiences are broad and complex in nature. They argued for new theorizing in the field of identity that recognizes the dynamics of identity construction (Roth and Tobin 2007). Past research in the field of affective learning in science has not attempted to illustrate connections between emotions, science identity and attitudes toward science. The current study addresses this gap in the literature by employing complexity thinking as an analytical perspective that sees science identity as manifest in emotions and recognizes the dynamism of the nature of science identity and its influence on attitudes towards science.

Analytic Framework: Complexity Thinking and Affective Learning

As argued above, there exists a gap in the literature on affective learning in science outreach learning environments, particularly in the area of how emotions are connected to science identity and attitudes towards science. In this study, complexity thinking is used as an analytic frame to investigate the following question: How can the learning environments of physics outreach challenges be understood through expressed emotions and affective constructs such as science identity and attitudes towards physics?

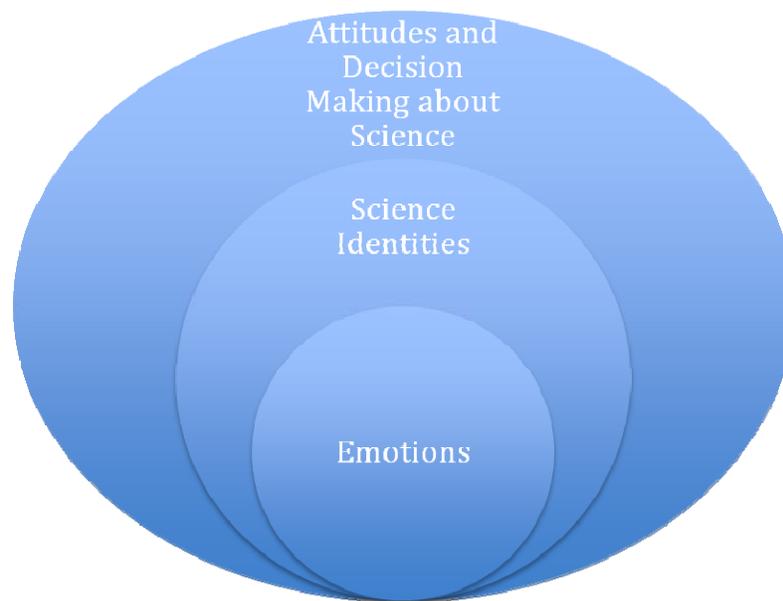
Complexity thinking is used as an analytic framework first by acknowledging that learning systems behave like complex systems. Secondly the researcher can look for features and characteristics of complex systems in order to better understand the structure and dynamics of the learning system (Davis and Sumara 2006).

Complex systems have been described as learning systems (Capra 2002) because they are interconnected, adaptive and self-organizing. A complex system is identifiable in that it is a system composed of many individual parts, each acting in their own self interest, but from which a whole that is greater (i.e., more intelligent) than the sum of the individual parts emerges. An ant hive is a classic example of a complex system where the ant colony is capable of finding food, building shelter and reproducing, but the capabilities of the colony are greater than the sum of the capabilities of individual ants. Informal and playful learning environments often display many of the properties of complex systems, such as the ability to *self-organize* into a whole that is greater than the sum of its parts (*emergence*) without the control of one leader (*decentralized control*) and are composed of complex systems *nested* within one another.

Current theoretical perspectives in the field of emotion apply ideas from complexity thinking and recognize the interconnectedness of emotion, identity, and learning (Weisel-Barth 2006). Several neurological perspectives attribute identity as emergent from emotions through the activation of memories (Damasio 1999; LeDoux 2002). Emotions help to mark, store, and retrieve memories (Johnson 2004). Thus, through the use of emotions, we can store and access memories and maintain continuity of sense of self (Damasio 1999; Donald 2001). Self or identity can be considered a unity which emerges for learners and can provide a “narrative layer [that] gives ideas a certain autonomy from personal experience and creates the possibility of abstract beliefs and public discourse” (Donald 2001, 322). Damasio (1999) describes identities as convergence zones that can be consistently and iteratively activated depending on the context, but that together form a greater whole, the autobiographical self which runs in the background at all times and allows for extended consciousness. Thus science identity is an affective construct that was interpreted in this study as an *emergent* phenomenon from the expression of emotions.

Employing a complexity thinking perspective makes explicit the dynamics of the affective learning system and enabled the researcher to develop a definition for expressed emotions and how they lead to the emergence of other affective constructs. Thus, for the purposes of this study, expressed emotions evoked during science outreach experiences were defined as leading to the emergence and manifestation of science identities that are adaptive and dynamic, and influence student attitudes towards and decision making about physics because they are all part of an interconnected and nested learning system (See Figure 3).

Figure 3. The complex system of affective learning. Three nested complex systems that each represent the emergence of different affective constructs: expressed emotions lead to the emergence of science identities, which lead to the emergence of shifts in attitudes and decision making about science.



The Study

This study employed interpretive, case-study methods (Creswell 2003; Stake 1995) to provide rich descriptions of students' affective experiences in the Physics Olympics competition and BC's Brightest Minds amusement park physics competition. The study participants were comprised of five teams of Grade 11 and 12 students participating in Physics Olympics events and three BC's Brightest Minds teams. The participants (35 in total) were interviewed twice, using a semi-structured interview format: before the event to determine their pre-event emotions and attitudes, and immediately after the event to clarify their expressed emotions during the event and to describe and interpret their post-event emotions and attitudes. Physics Olympics students were interviewed individually, however BC's Brightest Minds students were interviewed together with their partner. The interviews were audio recorded and transcribed verbatim for coding, theme searching, and interpretation.

During the events individuals and groups of students were also observed and video recorded. This data was complemented by recording their conversations during the events using lapel microphones and digital audio recorders. Qualitative data analysis and reporting procedures (Erickson 1986) and a complexity thinking perspective were used to identify and present emergent themes. All data sources (interviews, conversations and video data) were coded for expressed emotions. Emotions were coded if students explicitly said the emotion (e.g., "This is fun!") or if they were interpreted by the researcher as expressing an emotion (e.g., a student slamming a pencil on the desk was interpreted as frustration). The

researcher identified characteristics of complex systems such as positive feedback loops, critical points of instability and enabling constraints in order to explain the contexts that evoked emotions. Data coded with emotions were reviewed by a second pass of analysis for themes pertaining to science identity and students' sense of self (i.e., when students made connections between their emotions and their sense of self or of scientists). Conditions of emergence of complex systems were used to explain the emergence of science identity from the expression of emotions. The researcher made a final pass-through of the data to examine connections between science identity and affective constructs such as attitudes towards and decision making about science. Triangulation (Erickson 1986)—comparing data from the experiences described by students in interviews to their participation experiences recorded and observed during the event—supported the researcher's interpretations.

Results: Emotions, Identities, Attitudes towards and Decision-Making about Science

Students were observed to experience very strong emotions while participating. Four emotions were most frequently observed through coding of verbal and non-verbal expressions: fun, frustration, excitement and disappointment. Often positive and negative emotions were expressed simultaneously and emotional experiences were remembered frequently and favorably. When describing how they felt while preparing a pre-built design for the Physics Olympics students said:

Very glorious at moments and very hard at others. You feel a great sense when you accomplish something but when you realize you find something better it's like oh we have to do that again.

It's going to be, I don't know, wiping brows thinking hard. But it should be fun, this is surprisingly fun.

The researcher organized expressions of emotions into two themes according to how they were evoked: *context-* and *task-*evoked emotions. Elements of the *context* such as the social, voluntary, and novel nature of participating in an informal learning environment were key agents in evoking emotions. The social nature of both challenges created feelings of fun and motivated students to participate. Students expressed feelings of happiness, joy, and fun when they were interacting with others and when reflecting on their experience in post-event interviews. The competitive atmosphere and novel nature of the venue created expectations in students, which led to context-evoked emotions of excitement and also disappointment when they did not succeed. Students' level of success and frequent feelings of frustration and disappointment were also closely linked to the nature of the tasks in the events, in particular the level of challenge. Challenge was moderated through carefully planned time constraints and proscriptive rules which pushed the system (the team) closer to critical points of instability where emergence (emotions, identity, ideas) can occur. In this study, tasks that provided feedback about students' successes and failures evoked the strongest and most frequent emotions.

The analytical framework of the study viewed science identity as emergent from emotions, thus emotion codes were examined for evidence of science identity. Science identities were coded whenever students drew connections between themselves and the actions/characteristics of scientists or science concepts. Three different types of student-perceived science identities emerged: team science identities, individual student science identities, and stereotypical student science identities. Team science identities emerged when students talked about emotions and characteristics held by their team as a whole; individual science identities were identified when students talked about themselves as scientists; and stereotypical science identities referred to descriptions students made of professional scientists, or their perceptions of people who were good at science.

Manifestations of perceived science identities were identified, interpreted and understood depending on the conditions mitigating their emergence: 1) *diversity*, 2) *redundancy*, and 3) *neighbor interactions*. These conditions were drawn from literature in complexity thinking (Davis and Sumara 2006). In a complex system, *diversity* enlarges its range of possible responses to external circumstances and *redundancy* provides shared understandings in order to negotiate an unfamiliar learning space (Davis and Sumara 2006). While participating, students described their team science identities to include the notion of a diversity of skills. They described two types of people that they wanted to work with on these kinds of challenges: those with strong theoretical physics skills and those who could design and build, or who could apply physics principles to real-life situations. Before participating, students talked about skills that all scientists must have (redundancies), including good mathematical problem solving skills. This expression of stereotypical science identity is consistent with existing literature (e.g., Brickhouse, Lowery and Schultz 2000; Shanahan and Nieswandt 2011), but shifted and broadened with participation in the events to include a wider range of skills including the ability to work with others and apply physics concepts to real-world situations. Here one student describes her role on a Physics Olympics team:

If you look at the students, there are some that are academically smarter but there's people like me who—I'm not like all formula, this equals that, I'm more of a logical thinker so it's like, yeah that works, but wouldn't it technically...work better if you were to do it this way? And so I think that's why we all have something to contribute and then we all make it work really well.

When ideas were shared between individuals on teams or between teams, *neighbor interactions*, a condition of emergence, were said to be present in the complex system.

The presence of the conditions of diversity, redundancy and neighbor interactions facilitated the emergence of science identities from student expressed emotions. Through the expression of emotions, teams and individual students learned about how their own strengths and weaknesses compared to a larger student physics community. These emotions helped them to see where they fit within this student

physics community and allowed their perceived individual science identities to emerge. For example, one student said:

It [participating in Physics Olympics] shows me my place in the physics world.

This study also examined the impact of perceived science identities on affective constructs such as attitudes towards physics and decision making in physics. Complexity thinking draws attention to how aspects of a complex system (in this case, students' emotions and perceived science identities) are constantly adapting in dynamic interactions between the system and its environment. In an intelligent complex system, these adaptations are moments of learning. There was some evidence that emotions expressed during students' experiences at the Physics Olympics and BC's Brightest Minds events helped students learn about their strengths and weaknesses and to become more aware of coherences between their perceived individual science identities and stereotypical science identities, resulting in a shift in their perceived individual science identities. In this example, Derek uses his academic ability to justify his career choice, but after the event he also refers to other qualities, such as creativity.

Pre-event interview:

Derek: Yeah, I want to be some sort of engineer. I've always been strong in math, I like math. More than English and all the other courses.

Post-event interview:

Derek: ...I really want to be an engineer. By the end of it I wanted to be an aeronautical engineer. I don't know how I got that, I thought that was cool. By the end of this whole experience I really want to be an engineer. I just feel I have the creative mind for it and the smarts I guess.

These coherences have been shown to be important in student decision making in science, from courses to careers (Hannover and Kessels 2004).

The influence of perceived science identities on attitudes and decision making about physics was interpreted from what students said they learned about participating in the events. When students were asked what they had learned, they talked about and demonstrated shifts in their attitudes towards science, a process that occurred as a result of shifts in science identity. This conclusion is drawn from adopting a complexity-thinking perspective on these nested and interrelated systems.

Below is an example of how one student's attitudes shifted:

Pre-event interview:

Cam: What is physics? That's a tough one, I don't know. It's just applying math and formulas and concepts to find, to achieve something.

Post-event interview:

Cam: I've seen how physics is..., and what it does and what it incorporates. So it's not so much just math and calculating, you actually get to do stuff, research, and I found that cool.

Thus, perceived science identity proved to be a particularly important construct to pay attention to and understand in the complex system of affective learning that existed at the Physics Olympics and BC's Brightest Minds events. Emotions were expressed, perceived identities emerged and adapted, and adaptations were played out in the form of changing student attitudes towards and decision making about physics.

Recommendations for Playful Physics Learning Environments

The results of this study suggest that emotional learning experiences are rich learning experiences. Emotions are part of a complex system of learning where perceived science identities emerge and adapt, influencing attitudes and decision making about physics. In the science outreach environments that were studied, several characteristics and structures were observed that were powerful evocations for emotion. Considered broadly, these included the social nature of the activities (working in teams or pairs) and the challenge and novelty of the experience. In ordinary physics classrooms, students often work in groups on challenging activities that they have not encountered before, so why are Physics Olympics and BC's Brightest Minds contexts different? I believe that the bar is raised higher in these contexts: students are more social (organizing themselves into groups and meeting and engaging with teams from other schools) and spend their own personal time working on these projects. The activities are more challenging than those that most teachers risk presenting in their classes and, finally, the experience is particularly novel because it is a competition, held outside of class in a larger physics community than they have likely seen before. These elements are all powerful sources for emotion and cannot necessarily be repeated in a physics classroom, but some elements can be applied to other playful physics learning environments.

Tasks from both the Physics Olympics and BC's Brightest minds events that were most enjoyed by students were those with a hands-on, design component. Students found designing the pre-built challenges difficult but rewarding. These types of activities significantly influenced their attitudes towards physics by broadening their notion of the skill sets needed to succeed. They learned about the unpredictable, emergent, and playful nature of science. The strongest emotions were expressed when the challenge was difficult, which was usually moderated through strict time constraints and proscriptive rules. An important lesson from observing students learn at these events is that it does not necessarily take a lot of time (which is always an issue for classroom teachers) and that the students do not need to succeed to learn something from a challenging task. Students take a lot away from simply experiencing the uncomfortable space of trying to negotiate a difficult design challenge with their peers. Second, teachers should not shy away from creating emotionally stimulating, challenging learning experiences in their classrooms. The data collected in this study suggest that students often reconstruct negative experiences positively, feeling a special sense of accomplishment from being challenged in a particular way, or from being brave enough to even try. Third,

building on findings from Anderson and Shimizu (2007), strong affect improves memory vividness, thus emotionally evocative activities are more likely to be memorable and be reflected upon as students make decisions about physics. This research suggests that if students are sufficiently motivated, Physics Olympics and BC's Brightest Minds types of activities can evoke strong emotions and influence student perspectives on physics in positive new ways.

The results of this study also offer support for specific recommendations to be made for competitive learning environments such as these so that they can most closely resemble the structure and dynamics of a complex system.

1. The system should be as decentralized as possible. Participation must not be mandatory or have defined or prescribed roles. It is important to allow students' roles within the team to emerge depending on their diversity of interests and perceived strengths and weaknesses.
2. Positive feedback loops help to push a complex system away from equilibrium so that emergence is more likely to occur. The activities should be rule-bounded but flexible. Some parameters should be set and students work within them to explore the large array of possible solutions. Feedback from their successes and failures evoke emotions and motivate engagement.
3. Neighbor interactions help the dynamics of the system to move towards emergence. Do not isolate the team in preparation or competition. Providing an open space where students and teachers interact around their projects can promote self-organization, neighbor interactions and opportunities for students' ideas to bump against one another.

The results of this study were drawn from a relatively small sample of students who represent a particular type of high school student: those who are likely to volunteer to participate in physics challenges. The results can be generalized to this population of students, although not to typical high school students. Given that students from several different schools and in two different learning contexts were studied, conclusions can be drawn about the kind of learning that takes place in playful physics learning environments with characteristics similar to those examined in the current study.

Using a complexity thinking perspective, emotions are interpreted to be an integral part of an affective learning system. Conclusions illustrate that science outreach challenges are opportunities for science teachers to create playful and emotional learning environments that can have an important impact on their students' affective learning in science, particularly to shift their perceived science identities, attitudes towards, and decision making about, science.

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complexity thinking to explore the impact of social media tools on science teaching and learning.

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