VIGNETTES OF THE IGEM EXPERIENCE: STUDENT PARTNERSHIPS TOWARD AUTHENTIC LEARNING

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With the ever-increasing push towards authentic learning within post-secondary institutions, many approaches are being explored. One such method with a particular focus on real-world applications has been the International Genetically Engineered Machines (iGEM) competition program. At the University of Calgary, the iGEM program sees teams of undergraduate students tasked to develop a solution or product for an application of their choice in partnership with a faculty mentor. This paper presents the findings from an interactive workshop with post-secondary educators and a subsequent thematic analysis on vignettes collected from alumni of the University of Calgary iGEM program, focusing on how authentic learning was pivotal in their experiences. It was found that teamwork and science were recurring themes in the vignettes, while post-graduate life and personal growth supported the presence of authentic learning.

The call for authentic learning requires institutions "to align university teaching and learning more substantially with the way learning is achieved in real-life settings…." (p. 3) and to design curricula accordingly (Herrington & Herrington, 2006). There is debate in the field with respect to what defines authenticity, and one school of thought holds that authentic learning should address *real* problems, where this is taken to mean problems and situations that could be encountered by the students in their careers (Rule, 2006).

Herrington and Herrington (2006) suggest a more comprehensive definition that prioritizes cognitive authenticity over the actual task or problem itself, where the methods and approaches that are taught to students reflect those that they would employ in later practice. With 'authentic' taken to mean real-world, Herrington and Herrington go on to define the key characteristics of authentic learning as:

1. Providing authentic context.
2. Using authentic activities.
3. Access to role models.
4. Utilizing multiple roles.
5. Collaborating with others.
6. Reflecting upon the experience.
7. Articulating the outcomes.
8. Coaching from mentors.
9. Authentic assessment.

This focus on teaching in an appropriately scaffolded situational context was also highlighted by Billet (2001), where he surmised that to gain expertise within a subject that an individual must participate within the setting of that subject rather than learning in isolation.

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Billet goes on to describe how the various social practices of a workplace or discipline are key factors in his definition of expertise. Marton (1988) also commented on how the outcome of learning is directly tied to the context in which it was learnt, which highlights the importance for authentic education.

Jaeger and Nesi (2014) argue that the "one-size-fits-all" approach currently used in most university classes is not an effective reflection of authentic situations and, as such, does a poor job of providing opportunities for effective and authentic knowledge transfer. An alternative to this approach is to include opportunities for independent research into curricula, especially those that are scaffolded in such a way as to create opportunities for peer mentorship (Westberg and Leppien, 2018). A recent case study from the University of Newcastle employed such an approach in a behavioural ecology course (MacFarlane *et al.*, 2006). Their observations indicated stronger student engagement with the material and many of the characteristics of Harrington and Harrington's hallmarks of authentic learning were included in their work.

We have attempted to emulate such an environment in the iGEM (international Genetically Engineered Machines) program at our university. Students engage in scientific inquiry to solve a real-world problem in a team environment that is completely student-led, where students define, develop, execute, document, and disseminate their own project. All of this happens over the span of approximately 9 months, with paid full-time work over the spring and summer terms and volunteer work during the fall semester. Faculty members, research assistants, and graduate students are there to mentor and to support the iGEM students. To cap each iGEM season, the Jamboree gathers teams from all over the world to compete for medals and prizes by disseminating their work through collaborative websites, posters, and oral presentations. As for any competition, the objective is to perform well and win awards that are adjudicated by professionals within academia and industry.

But what of the learning of these students? Is it authentic? To begin to answer those questions, we gathered short vignettes from former team members reflecting on their iGEM experience. A total of six vignettes, ranging from one to two pages in length, were collected in April of 2018 by asking students from the 2011, 2012 and 2013 University of Calgary iGEM teams to reflect on their experience in the iGEM program in terms of the conference theme of "Students as Creators, Drivers, Innovators and Collaborators in Postsecondary Education". This paper describes and expands upon an interactive session where post-secondary educators at a recent conference read and discussed those essays.

The specific objectives of this paper are:
(1) To describe the interactive session and to review the themes identified by the session participants;
(2) To define themes in each of the vignettes, using the scheme of Braun and Clarke (2006); and
(3) To interpret these themes in terms of authentic learning, as characterized by Herrington and Herrington (2006).

DESCRIPTION OF THE INTERACTIVE SESSION

After a brief introduction to iGEM and authentic learning principles was presented, the conference participants worked in pairs to read a vignette and to identify major themes related to teaching and learning. When the larger group re-convened, everyone listened to an audio recording of each vignette, and the pairs who had studied the text led its discussion, listing the

themes they had identified, and inviting comments or additions. Finally, the conference participants wrote a brief reflection, which was collected at the end of the session.

The conference participants identified several themes in the vignettes during the relatively short time frame of the session. Chief among these were themes related to personal growth: confidence, self-awareness, independence, industry, motivation, ownership, and dealing with uncertainty. The reflections of the participants echoed these themes:

"*Giving students the chance to take ownership of their own projects leads to…confidence and very productive experiences…*"

"*…promoting transformative experiences for undergraduate students…provide students with a platform for personal development.*"

"*Creating a difficult and amazing challenge for students…not typical but something that will be remembered…a life-changing experience.*"

The conference participants also highlighted themes of multiple perspectives (multidisciplinary, new way of thinking), teamwork and collaboration, and future impact (transition/transferable skills, preparing for next step). Within tight time constraints, the conference participants had identified major themes which would later see confirmation, refinement, and further analysis through the lens of authentic learning.

THEMATIC ANALYSIS OF VIGNETTES

After the conference, we conducted a thematic analysis of the vignettes using the following general scheme (Braun & Clarke, 2006):

(1) Knowing the data (i.e., reading and re-reading the vignettes);
(2) Generating initial codes (i.e., interesting features across the data);
(3) Searching for potential themes (i.e., patterns, combinations);
(4) Reviewing themes (i.e., in relation to the initial codes and the whole data set);
(5) Defining and naming themes (i.e., identifying the essence of the theme); and
(6) Producing the report.

The vignettes were analyzed using this approach with the NVivo 12 qualitative data analysis program from QSR International (Victoria, Australia). A word frequency analysis (Figure 1) was performed to identify initial keywords that were used as the basis to begin coding the references within the data.

Figure 1. Word frequency analysis of iGEM vignettes by NVivo 12 qualitative data analysis program from QSR International (Victoria, Australia).

This approach was performed in an iterative manner to more deeply explore the emerging themes in this dataset. In the thematic analysis below, we identified three major themes: teamwork, science, and post-grad life.

Teamwork

A theme that emerged in all of the narratives was that of teamwork. In comparison to traditional academic "silo" research, the students found that the team aspect of the iGEM program allowed them to create a project that was greater than any single scientist could have done on their own. It was also mentioned in half of the vignettes that the multidisciplinary nature of these teams helped to build towards what the team members felt was a stronger project. This theme was exemplified by quotes such as "*It was an opportunity to work in a team, a team with dedicated people from various disciplines and backgrounds who were all trying to work together to solve a big problem that was plaguing humanity…*". Another commented on how the team worked together by saying that "*To be able to achieve all that we did in 6 months required solid planning, strong communication, and collaboration…*".

iGEM team members are mutually engaged with one another, coordinating their efforts to solve a problem or create a product. In their discussion of cross-disciplinary team learning and performance, Schaffer et al. (Schaffer, Lei, & Reyes Paulino, 2008) cite Vygotsky's notion of how individuals learn through an iteration of ideas and construct new knowledge through collaboration and social interaction. One student highlighted this interaction by pointing out that "...*we quickly started vetting and iterating upon each other's ideas before coming to our professor with a more developed version.*". This collaborative construction of knowledge is a hallmark of authentic learning (Herrington and Herrington 2006).

Here, the multidisciplinary nature of iGEM is seen as integral to teamwork, however, the consideration of multiple roles and perspectives that arise also characterizes authentic learning (Herrington and Herrington, 2006). These soft skills are often not explicitly taught in classes, which makes the iGEM program an excellent development opportunity for the students. One student succinctly summarized her experience leading a team by saying that "*I was learning how to manage people, how to delegate, how to trouble shoot complex scientific problems and how to resolve conflict; all things I hadn't learned in my courses.*".

Science

Another common theme was the chance to be involved in, as one put it, "...*real cutting-edge research...*". Two thirds commented on the scientific nature of the iGEM projects they were involved in, with most mentioning that the ability to pursue their own scientific ideas was rewarding. One vignette spoke about how students were "...*given free rein to implement our plans...*" and that the professor was "...*a sounding board and a collaborator...*" in the project with the students. Another student also touched on the independence of the student team, saying that "*It was a place to come up with your own new ideas and solutions...*".

iGEM team members engage in scientific inquiry towards solving a real-world problem, which provides an authentic rationale and motivation for their work. Their experimental strategies must be tested and developed iteratively, reflecting the complexity of real-world tasks. All of these provide instances of the cognitive authenticity so vital to authentic learning.

The role of faculty as a mentor and collaborator speaks to the coaching and scaffolding of support found in an authentic learning environment (Herrington and Herrington, 2006). While student-driven, the iGEM experience happens in a learning environment that can provide expertise to bridge gaps in training and understanding.

Post-grad Life

Interestingly, almost every vignette commented on how the University of Calgary iGEM experience had prepared them for what they had gone on to do after graduation. Their next steps have ranged from pursuing higher education to founding startup companies. One student said that "*What I didn't realize at the time was that this philosophy for designing products was the way companies and other industries think about creating things and building this skillset was going to provide me a massive asset in the future*". Others commented on how the teamwork and interdisciplinary nature of iGEM helped them later on in their careers, with one student saying that "*I learned to work collaboratively with a variety of people across disciplines. It is something that I apply daily to my present work in my PhD*".

This theme of the impact of the iGEM experience on one's future hints at the fruits of authentic learning: how ways of thinking and skills sets were applicable and useful in the real

world; and how having worked in teams of individuals with different perspectives prepared them for teams in the workplace.

A sub-theme that ran through all of the major themes was the notion of personal growth, which the session participants had strongly identified in their brief encounter with the vignettes. We suggest that it is this personal growth, whether in confidence or creativity, or in self-knowledge and the discovery of one's passion, which is tied to the authentic learning experiences of these students and has had such a positive impact.

SUMMARY

To answer the question of whether the iGEM experience constitutes authentic learning, we conducted a thematic analysis of vignettes written by former iGEM team members and interpreted those themes through the lens of authentic learning. Of the major themes we identified, teamwork and science bore the cardinal characteristics of authentic learning, while post-grad life and personal growth supported the authenticity of learning. From these vignettes, as well as the results from the thematic analysis, we conclude that the team-based collaborative nature of the iGEM program provides a fertile ground for authentic learning experiences as defined by Harrington and Harrington (2006). Interestingly, two of the themes identified had little to do with the topics of the student research project, rather they focused on the environment and how it impacted the students (teamwork & personal growth). This bodes well for the transfer of such a process to other disciplines. While the iGEM program itself is geared solely towards genetic engineering projects, it is possible to expand this model to other disciplines by, for example, creating project teams within a larger class framework for intra-university events. Further study is currently underway at our university to determine the key hallmarks that enable the iGEM program to have such a large impact on the authentic learning of the program participants and to explore methods to translate this into other learning settings.

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