Special Session: Fostering Metacognition Development in a STEM Context

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***Abstract*—An educational incubator in Purdue University's Polytechnic Institute has been experimenting with highly integrated methods to facilitate, assess, and evaluate student learning. Comprised of transdisciplinary faculty and students, one of the basic covenants is to intentionally and repeatedly balance Humanities and STEM concepts by way of open-ended problems affecting humanity and the planet. The learning experience environment tries to integrate faculty and students from widely different disciplines in scenarios where cognitive and metacognitive development is encouraged and explored. This special session will engage attendees in examples of activities that can help students become self-aware of the power of music on their physiology and imagination while also integrating problem-solving and other STEM related concepts. Participants will take away ideas and techniques that they can add to their own palette for fostering integrated learning and metacognitive development. This session aligns with FIE's focus on innovations in classroom techniques.**

I. Description

Since August 2013 an educational incubator in Purdue University's Polytechnic Institute made up of transdisciplinary faculty and students has been developing and experimenting with highly integrated methods to facilitate, assess, and evaluate student learning. One of the basic covenants is to intentionally and repeatedly balance Humanities and STEM concepts by way of open-ended wicked problems affecting humanity and the planet. The learning experience environment tries to integrate faculty and students from widely different disciplines in scenarios where cognitive and metacognitive development is encouraged and explored. Metacognition, or "thinking about thinking", also encompasses self-awareness and self-regulation, memory monitoring, and meta-reasoning [1]. When developed, these capabilities are used to regulate one's cognition, learning, and evaluation of ethical and moral rules, forming the basis for informed and grounded decision-making. In one learning module, students were guided through a series of active learning experiments to explore their individual physiological changes resulting from the absence and presence of music and sound. They were also guided through an exercise of mentally processing music to expose images and narratives in their "minds eye".

II. Goals and Novelty

One of the goals of this session is to engage attendees in attempts to foster metacognitive awareness and development using sound and music in a STEM context. Another goal is for attendees to relax and enjoy listening to music for the purpose of ones own self-awareness and the exploration of the images created in ones mind that forms a story or narrative while listening to music. The audience for this session are those interested in novel ways to expose students to their own self-awareness using techniques that mask data gathering and analysis (STEM concepts) behind sensory and emotional exploration (Humanities concepts).

The session is novel and thought provoking in ways that challenge participants to relax and fully engage with their senses and imaginations, integrating their experience with scientific and technical experiments, analysis, and thinking. Sensory awareness and aesthetic experience are not commonly associated with the central activities of STEM learning, yet these are components in fostering a student's ability to integrate learning [2]. The facilitators use an integrative framework where sensory awareness and aesthetic engagement go beyond being an added component or aspect of learning, but become a central aspect of learning and developing competency in STEM disciplines.

III. Interactivity

The session will be highly interactive. Attendees will be immersed in two main activities. The first activity explores the physiological changes that occur in the absence, then presence of music. Attendees first will download and learn to use a common smartphone application used for monitoring heart rate. This in and of itself can be a problem-solving activity. Participants in pairs will then gather heart rate data in the absence, then the presence of music. Basic descriptive statistics will be calculated from the collected data and results from analyzing these data will be shared among the participants and facilitators. The data collection, descriptive statistics calculation, and analysis portion of the activity that is most closely associated with STEM activities. The sharing

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of data, particularly qualitative data of the experience relates more to an emotional (Humanities) experience. In the second activity participants will engage each other and the facilitators in descriptions of their individual mental images and stories produced by listening to a short piece of music. The idea is to encourage the participants to compare and contrast each other's perceptions based on their individual application of their cognitive and metacognitive capabilities, where "Metacognitive experiences are any conscious cognitive or affective experiences that accompany and pertain to any intellectual enterprise" [1]. Once participants begin to articulate their perceptions they will be asked to consider questions relating to geography, the time in history, the "story", "narrative", or "context" of the music (what is happening), and even the materials that make up some of the instruments performing the music, bring full circle emotional and STEM-like analyses of the experience.

IV. Content and Agenda

The 80-minute session will open with a short introduction to metacognition and how sensory awareness and aesthetic experiences are not commonly associated with the central activities of STEM learning. Attendees will then participate in two activities, the first slightly more technical than the second, but both masking data collection and analysis behind sensory and emotional exploration. The session agenda is as follows (h:mm).

0:00-0:10 - Introduction: A brief introduction of the facilitators followed by an explanation of metacognition, why it is important for engineers to develop it, and how the following experiments are intended to help foster the individuals discovery of it. The facilitators will also present a brief introduction to the aspects of music and human physiology and engage a short group discussion on how listening to music alone can create mental images, stories, and narratives. This is presented in lieu of discussing readings normally assigned to students. The facilitators will also use this time to begin the preparation and setup for the first experiment.

0:10-0:40 - Activity 1: The setup will be completed in the first 5 minutes. Two sets of data will then be collected involving pairs of participants, one to gather resting heart rate data then the second, to gather heart rate data in the presence of music. Each of these data sets should take approximately five minutes each to collect. Data collection will be followed by an exercise to determine the average resting and heart rates from the two scenarios. Comparisons will be made among groups of participants, taking approximately 10 minutes. Finally, a wrap up of 5 minutes will take place where results from earlier experiments with students will be compared and contrasted.

0:40-1:10 - Activity 2: The setup will be completed in the first 5 minutes. Data collection will involve all attendees listening to a short musical piece, followed by a discussion and analysis led by the facilitators to draw out the "story" told by the piece. This should take roughly 10 minutes. If necessary, the listening step will be repeated to give the attendees a second opportunity to immerse themselves in the musical piece. A wrap up of approximately 5 minutes will then take place where again results from earlier experiments with students will be compared and contrasted.

1:10-1:20 - Conclusions: The facilitators will follow up with quantiative and qualitative data from students who have participated in similar experiences. The attendees will then be polled for any remaining questions or comments.

V. Take Aways

Attendees of this session will walk away with experiencing actual examples of novel ways to utilize an integrative framework where sensory awareness and aesthetic engagement go beyond an added component or aspect to STEM learning, but become a central aspect of competency and metacognitive development in STEM disciplines. They can use this session as an experience to inform and motivate the development of their own ways to inject fun into the learning environment while addressing and assessing technical, sensory, aesthetic, and metacognitive development.

VI. Facilitators

All four facilitators have been instrumental in creating and implementing Purdue University's first competency-based degree program. The Transdisciplinary Studies in Technology program features students developing their own plan of study to follow their passions and professional interests under the guidance of an adviser and faculty mentor. Students develop and demonstrate broad competencies that transcend disciplines and prepare them for life in the 21^{st} century.

Professor Jeffrey Evans has taught electrical and computer engineering technology courses for over fourteen years. Since 2013 he has been immersed in competency-based education practices that combine Humanities and STEM disciplines in learning environments that transcend disciplines. He is also an avid musician (flugelhorn) and composer.

Drs. Justin Seipel and Michael Smith are Transdisciplinary research and education specialists respectively, with combined research and classroom experience spanning domains from Biology to Engineering, Economics to English, and Entrepreneurship to Media. They currently spearhead the Purdue Polytechnic Institute's Transdisciplinary Studies in Technology program.

Professor Amy Van Epps has taught information literacy in engineering design for over fifteen years. She has published extensively on information literacy instruction, information habits of engineers, and assessment of information literacy skills in an engineering context. She is also an avid vocalist, participating in local singing groups.

REFERENCES

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