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## **AC 2011-2056: EMOTIONAL INDICATORS AS A WAY TO INITIATE STUDENT REFLECTION IN ENGINEERING PROGRAMS**

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# Emotional indicators as a way to elicit authentic student reflection in engineering programs

## Abstract

Reflection is increasingly recognized as central to student learning and professional development. There is, however, a lack of defined, systematic strategies to stimulate purposeful student reflection and overcome the inherent difficulties of the engineering cohort to engage in reflective thought. This paper theoretically develops a framework of emotional indicators to support student reflection on critical learning incidents. The framework is explicated through early data from a qualitative study that employed these indicators in student focus groups.

The framework systemizes feelings that accompany critical learning incidents and can, in turn, be used to trigger students' recall of those experiences. The following five categories are proposed to organize the feelings according to the learning context they occur in: **novelty, challenge, progression, exploration** and **insight**. This framework is then used to derive specific triggers which can be used in reflective exercises to help students identify and recall experiences that are crucial to their individual learning.

The triggers were trialled in a series of reflective focus groups to explore student learning in an interdisciplinary synthesis and design studio with engineering and art students. The focus groups were digitally recorded and transcribed for the subsequent interpretive analysis using the qualitative data software NVivo8. The paper draws on early data from this study to (i) illustrate some of the above-mentioned five categories through a thematic analysis of the students' shared lived experiences, and (ii) explore the usefulness of the procedure in eliciting students' memories of transformational learning experiences. The early analysis of the students' suggests that identifying emotions that accompany significant learning moments provides an intuitive and meaningful access for students to reflect on their learning.

## Introduction: The need for reflection and its role in student learning

*“The difficulty [...] is likely to present itself at first as a shock, as emotional disturbance, as a more or less vague feeling of the unexpected, of something queer, strange, funny, or disconcerting.”*

John Dewey (1932)

Critical student reflection is increasingly recognized as a crucial part of engineering students' overall learning<sup>1-6</sup>. This is highlighted by a number of trends that focus the attention of the engineering educator on aspects such as students' awareness of engineering practice being embedded in social contexts and their future role as professionals with ethical and societal responsibilities<sup>7-9</sup>. In part, such broader competencies are inherently reflective and point to the need to specifically support students' development as critically reflective practitioners<sup>10, 11</sup>.

Additionally, the role of reflection in facilitating student learning on the level of specific content or skills <sup>12</sup> and in supporting motivation <sup>13</sup> has been widely used across many disciplines .

### **Research need: Reflection in engineering learning – existing approaches and persistent challenges**

In line with the broader developments outlined above, reflection has been used in various contexts in the field of engineering <sup>4, 5, 14</sup>.

On the educational level, reflective journals have received a significant share of attention as a means to facilitate student learning and as a possible avenue to provide evidence of students' development of broader learning outcomes in the context of program accreditation <sup>15</sup>. More recently, electronic and web-based approaches have also been introduced (e.g. <sup>1</sup> to implement reflection as a part of engineering curricula.

In the professional context, reflective elements such as portfolio approaches are used to facilitate professional development and serve as an element of professional accreditation processes to demonstrate outcomes from experiential learning <sup>3</sup> in the workplace. In the Australian context, for example, engineers submit “practice reports” with “written career episodes” <sup>16</sup> to reflect upon and demonstrate progression in specific aspects of the competency requirements defined for the national chartered engineering status.

There are, however, persisting difficulties in fostering reflective thought in students <sup>17</sup>. Duley <sup>18</sup>, for example, describes this as: “The skill of experiential learning in which people tend to be most deficient is reflection” (p. 8). In the context of engineering education, the student cohort has been identified as particularly resistant to engaging in, or developing, reflective thought <sup>19</sup>.

We contend that these difficulties are in part due to a lack of specific approaches to initiate deliberate reflection. While formats to structure and engage in reflection exist (see above), a particular challenge is to initially elicit and identify the critical learning experiences that are most beneficial as the subject for structured reflection <sup>20</sup>.

To address this challenge of stimulating initial reflection, the following sections theoretically develop a framework of emotional indicators that accompany critical learning incidents and can, in turn, be used to trigger their recall for the purpose of deliberate reflection. The framework is developed based on prior experiences in facilitating reflective focus groups <sup>20</sup> and research that captures some of the emotional aspects of the initial stages of reflection <sup>2, 6, 11</sup>. Drawing on early data from an empirical study of an engineering synthesis and design studio <sup>21</sup> which incorporated a strong reflective component, the latter part the paper explores the framework through an early thematic analysis of students' accounts of reflective learning experiences.

### **A framework of emotional indicators of critical learning incidents**

The purpose of the framework developed in the following paragraphs is to provide a wide range of triggers that can be used by the educator and the learner to elicit critical learning incidents as a starting point for purposeful reflections. The educator can use the framework in Figure 1 to

develop trigger statements to use in various formats of structured reflection, for example the focus group protocol described in <sup>22</sup>, to stimulate students' reflection process. The trigger statements contain manifestations of emotions that resonate with students' experiences of learning situations, thus triggering the recall of those critical learning moments. For the learner, the framework can be used to independently explore the space of possible learning experiences through the range of emotions and their manifestations presented.

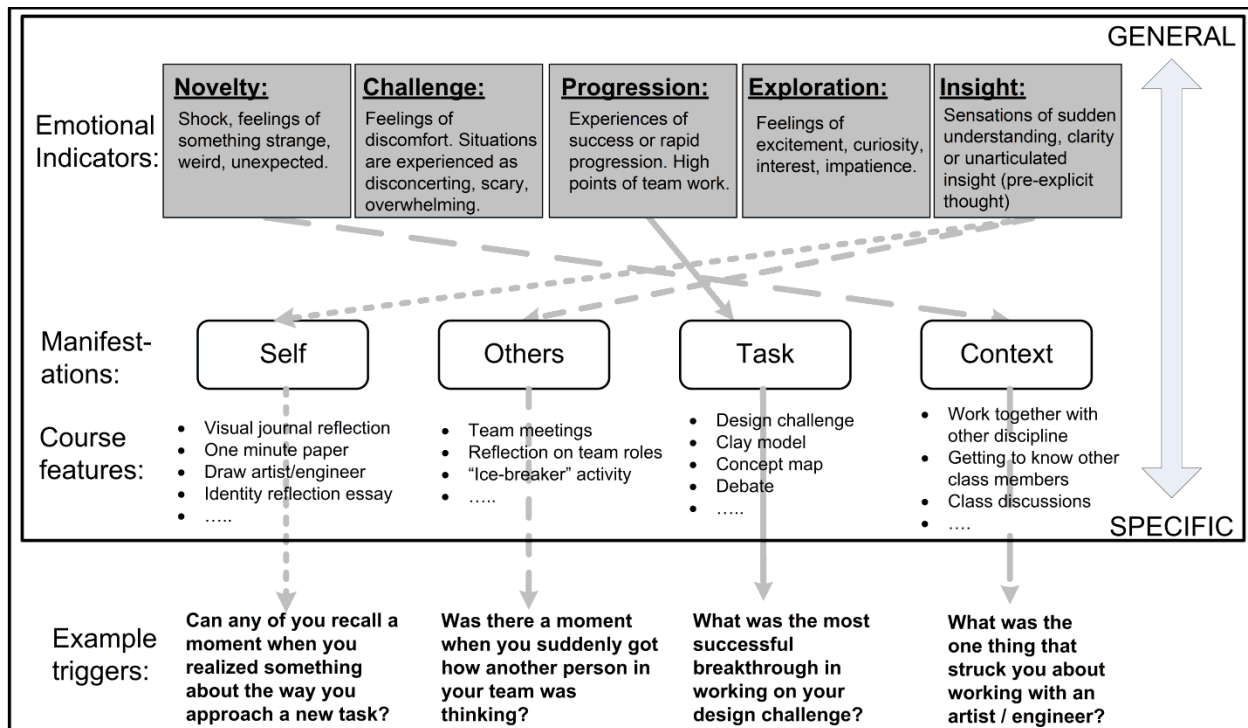
The concept of emotional indicators is based on the notion that critical learning incidents <sup>23, 24</sup> are accompanied by a range of emotions the learner experiences. Learning in this sense is conceptualized as the process of existing knowledge or conceptions being challenged by an experience <sup>25, 26</sup>. This discrepancy between prior learning and the situation is experienced as an "emotional disturbance" as described in the introductory quote by John Dewey <sup>2</sup>. In the context of professional practice, Schön <sup>6</sup> describes these moments as "the practitioner allow[ing] himself to experience surprise, puzzlement, or confusion" (p. 68). The subsequent process of reflection is then the attempt to make meaning from the situation and incorporate the experience into altered knowledge structures or assumptions <sup>25</sup>. Atkins <sup>27</sup> describes this as "an awareness of uncomfortable feelings and thoughts is followed by a critical analysis of feelings and knowledge leading to the development of a new perspective" (p 1191).

The moment that can initiate the reflective or experiential learning process is thus the emotional disturbance and the particular feelings experienced in a situation. In Schön's description, the reflective practitioner ideally "allows himself" to experience these emotions and is aware of their meaning for his learning process. Returning to the difficulties that students experience with reflection, we contend that educators need to facilitate this process of recognizing the emotional disturbances, attributing meaning to them and becoming comfortable with them.

The framework, illustrated in Figure 1, presents a structured way to facilitate this process. It is organized along two dimensions, with the horizontal axis specifying the categories of basic emotional indicators and the vertical dimension the increasing degrees of specific situations in which the indicators potentially manifest. The figure illustrates how the framework can be used to design example trigger statements by following various pathways as indicated by the arrows.

### *Emotional indicators*

Along the emotional indicator dimension, the framework provides a range of different emotions that students are likely to experience in critical learning situations. The learning contexts of novelty, challenge, progression, exploration, and insight thus provide the categories to organize the particular feelings. These are described in more detail as follows:



**Figure 1:** Framework of emotional indicators and levels of manifestations

- **Novelty** captures general feelings of surprise when the learner encounters an aspect of a situation that is unexpected or unknown.
- **Challenge** specifies this further to categorize feelings of discomfort caused by the novel experience. Often this is the main category in which researchers describe the emotions that form the triggers for reflection. Atkins et. al <sup>27</sup>, for example, describe “the first stage of reflection [as] triggered by an awareness of uncomfortable feelings and thoughts” (p. 1189). This conception does, however, limit the emotions relevant for student learning to negative feelings which might in turn exclude some significant learning moments from consideration.
- The next category of emotional indicators thus describes the positive feelings associated with **progression** when the learner is able, perhaps to her own surprise, to resolve a new situation. This can occur in a team work situation or when an individual student follows her intuition or simply tries a certain approach to a new setting. The learning opportunity here would be to make explicit and re-utilize the particular behavior or strategy.
- The category of **exploration** includes feelings of excitement and curiosity that many learners experience when encountering new and open-ended situations in a supportive learning environment. Such experiences can be a good indicator for significant learning opportunities. In addition, the positive associations are likely to promote subsequent analysis and development processes.

- Sensations of sudden understanding or clarity are described in the category of *insight*. Such learning moments might have been preceded by a number of smaller critical incidents and have been considered by the learner without finding explicit expression. Identifying the culmination of such processes in an ‘aha moment’ can serve to solidify the insight or identify and analyze the prior learning leading up to it.

### *Levels of manifestation*

The second dimension of the framework (Figure 1) considers the manifestations of the emotions described above on varying levels of specificity. This explores the range from general, vague feelings associated with the learning situations of novelty, challenge, progression, and exploration, to sensations that are associated with very specific elements of the learning experience (e.g. team meeting, debates, etc. in Figure 1).

On the most fundamental level the emotional indicators can be experienced as connected to the four aspects of task, others, context, and self.

- The category *task* encompasses students experiencing any of the emotions described above when engaging with the learning materials. This can constitute individual learning in traditional courses or aspects of problem-based or active learning formats. In developing prompts for reflection on a particular class, the educator can, for example, draw on specific elements of the course design that were likely to be a significant part in students’ overall learning experience.
- In collaborative learning environments, other students or instructors are likely to constitute a rich source for potential learning opportunities. This can mean that students directly learn from observing or interacting with *others* or they can be the catalyst that challenges the student’s perception of learning content or process in positive or negative ways. This demonstrates again that the manifestations described here can be associated with any of the emotional indicators described above.
- Another significant source of stimuli for reflection can emerge from the wider educational setting<sup>28, 29</sup>. These aspects of the *context* can concern the larger structure and design of a course, the character of the cohort, or include aspects of the culture of the department or institution. Depending on the purpose of the reflection, prompts developed in this category can explore the effects of particular features of a course or program.
- The category of *self* encompasses manifestations of the emotional indicators that are concerned with the individual learner. In contrast to the description of task above, which was concerned with the external learning content, the category ‘self’ targets aspects of the course or program that were likely to generate meta-cognitive processes. Any of the above emotions can emerge when the learner negotiates process aspects of his or her own learning. This can, for example, range from surprises about the failure or success of a particular learning strategy, to larger disturbances concerning the extent to which the learner experiences a fit with the learning environment or the disciplinary context<sup>30, 31</sup>.

### *Use of the framework*

The framework presented above maps out a space of potential triggers for meaningful reflection along the dimensions of the emotions experienced in critical learning moments and the types of specific circumstances in which these emotions manifest. The purpose of reflection based on this framework is to systematically explore this space, thus increasing the likelihood of significant learning moments to be recalled and subsequently analyzed. For an educator facilitating reflection, or a student reflecting independently, this means considering which potential learning experiences could have occurred in a particular context and how their recollection can be triggered without confining the range of possible learning incidents.

In developing and using trigger statements to prompt reflection, it is thus beneficial to explore each category of emotional indicators along the dimension from general (to leave room for anything to be considered) to specific (to trigger particular recollections that would not be accessible without being prompted more directly). Considering the category of challenge, a general prompt could be, for example:

*“Can you try to recall the most frustrating moment during the past semester?”*

Once the students’ recollection on this general level are exhausted, a more specific manifestation of the emotional indicator could be useful, such as:

*“Thinking back to your project team meetings, was there a particular time when you felt overwhelmed by the design task?”*

In both cases, the triggers would need to be developed from the context and the teacher’s experience of the course to target aspects that were likely to have constituted a significant learning moment. The pathways indicated by the arrows in Figure 1 illustrate further explorations of the space with resulting triggers on various levels of specificity. As described above, the triggers can be used in any of the existing formats for structured reflection, ranging from on-line portfolios to in-person reflective focus groups (for an example of a semi-structured focus group protocol that utilized similar trigger statements see <sup>20, 22</sup>).

### **Early empirical data of the use of the emotional indicator framework**

The following presents the context of a larger study in which the framework presented here was used to develop prompts for reflective focus groups. The analysis of the students’ reflections in the subsequent section is used to explicate and further explore the categories of emotional indicators presented above. It is not intended to serve as a comprehensive evaluation of the approach but rather supplies example outcomes from the student reflection to illustrate the range of different reflections observed in the study.

#### *Context of the study*

The study was set in the context of an innovative synthesis and design studio <sup>21</sup> with undergraduate engineering and art students (n=19). This interdisciplinary course was based on

group projects in small teams with equal numbers of art and engineering students. The project teams worked on a semester-long, ambiguous, and open-ended design challenge while engaging in a range of class activities to foster their creative development. A significant part of this course was a reflective component consisting of the use of visual journals, targeted minute papers, reflection through art making, and a series of reflective focus groups at three points during the semester. The focus groups with six to eight students each lasted for about 45 minutes and followed the structure outlined below:

1. At the beginning, students were introduced to the purpose and method of the reflective exercise and presented with a list of triggers that were designed specific to the course using the framework discussed above. The group was given five to ten minutes to peruse the list of triggers offered. The facilitator emphasized that the purpose was not to find an association with each trigger but rather to see which of them ‘rang a bell’ and resonated with one of their own experiences. During this time the participants were encouraged to take brief notes about the situations that came to mind to serve as the basis for the subsequent discussion.
2. The next stage of about 35 – 40 minutes consisted of an open, interactive group discussion in which the students initially shared accounts of the situations recalled in the prior phase. In the discussion, these stories then served as a trigger for the recollections of other students to also be explored through detailed accounts of the situation. If necessary, the facilitator could return to the students’ earlier notes or introduce additional triggers to revive a halting discussion, or explore a particular aspect in more detail. The focus of the discussion phase was to establish detailed accounts of the participants’ critical learning experiences.
3. As a later individual exercise, the student were asked to compile a written account of one of their learning experiences and analyze it in terms of their learning and formulate decisions for future, similar situations for an example of a useful structure for the analysis see: <sup>32</sup>.

#### *Thematic analysis of student reflections in the focus groups*

The focus groups in the context of the study were digitally recorded and transcribed for the subsequent analysis using the qualitative data software NVivo8. The following presents an early thematic analysis of the focus group transcripts. The presentation in the context of this paper serves two purposes: (i) to explicate and explore some of the categories of emotional indicators through students’ lived experiences. This is intended to provide a more concrete sense of how the framework can be used and applies to a specific educational setting. (ii) to explore the usefulness of the framework by illustrating the range of reflective insights the students gained through the focus groups. The quotes presented here do not constitute the entire evidence base for each category and are not intended to provide a comparative analysis of the engineering and art cohort. The illustrations offered here are, rather, provided to give an authentic view of the use of the framework.

The two themes presented below demonstrate that students’ reflection spanned both recognitions concerning specific aspects of their learning and profound insights relating to fundamental processes of identity formation.



### Meta-cognitive insight – ambiguous group projects

The central element of the course consisted of group projects in which interdisciplinary teams worked on a semester-long, ambiguous, and open-ended design challenge. This provided the context for a range of significant learning situations and a number of triggers in the focus groups were targeted to elicit recollection of students' experiences concerned with the ambiguity and the team aspect of the projects.

In this context, Drew, a female engineering student commented:

*“Because of the [...] lack of brainstorming/investigation, I felt really confused as to what we were doing – I wasn't seeing what my group had in mind. But for the sake of cooperation and completion of the project, I tried to finish the assigned tasks. Looking back, I wish I would have interjected and regulated at the start“.*

In this recollection, the student describes an early team meeting in the initial phases of the project concerned with task clarification and scope definition. One of the prominent emotions she recalls is confusion relating to the **novelty** and the **challenge** category. Based on the memory of this emotion, the student was able to authentically recall the situation and described how she dealt with the feeling of discomfort by following the majority of the group. In the context of the reflection, however, and with the benefit of looking back on the project, she realized that the direction of her group was ill-defined and not based on sufficient initial information or ideas.

It is possible that some students would recognize such learning opportunities on their own, but, the structured reflection afforded this student with the opportunity to learn a central lesson of project work and the dynamics of early team formation. In this sense, Drew concluded that she would more strongly voice her views in this “forming” phase<sup>33</sup> and urge the group to engage in more early brainstorming and problem definition.

### Identity reflection – self-definition as learner

The interdisciplinary nature of the course and the diversity of the students provided a range of stimuli for students to consider larger questions that concerned various aspects of their identity as a learner and a developing professional. Some of these processes were observed anecdotally by the instructors and thus targeted prompts were introduced in the focus groups to elicit such critical learning moments.

Sidney, a male art student, articulated such a learning experience in the focus group:

*“Working in groups has taken the ideas and challenges in this course beyond anything academic and to a level where I have to think about my humanity. When working in a group for the entire semester I had to engage ideas about acceptance, humility, and anger management. Recently, working on our puzzle pieces, some group members were not putting in the same amount of effort as myself. I am very invested in this project and I was expecting everyone else to put in the same amount of time as myself outside of class. I was horrified*

*when one group member said to me don't worry we'll get a 100% anyways. I am not in this for a grade or to meet the expectations of my professors. I am here to learn, exceed expectations, and do the level of work I think is necessary to be successful."*

Looking back over the entire experience of the course, the student is able to articulate a whole range of emotions experienced throughout. He describes this process of engaging with his group as experiencing tensions between his own ways of learning and those of his team members. The emotions are largely situated in the **challenge** category but also transition into the **insight** category when partial clarity was reached about a particular situation.

The focus group was an opportunity for the student to synthesize this gradual learning into a profound insight concerning his self-definition as a learner. From the contrast to the perceived assessment driven learning styles of his team mates, Sidney is able to define and articulate his own aspirations as a self-directed learner with a focus on professional competency ("do the level of work [...] necessary to be successful") and not on immediate grades in the course. The student most likely displayed this attitude in other courses too, but the reflection allowed him to explicitly articulate and consolidate this insight for future and life-long learning experiences.

In summary, both quotes demonstrate that the recollection of the learning moments was triggered by their association with a particular emotion and that through a retrospective, structured process, both students were able to translate these experiences into profound and explicitly articulated insights.

## **Discussion**

Fostering reflection in engineering programs was discussed in the beginning of this paper as a critical element in efforts to prepare students to become critical, reflective practitioners. Existing approaches focus mainly on structuring and facilitating reflective analysis in a number of formats. A key factor in the persisting difficulties with reflection, however, is to support students in initially identifying critical learning incidents. To address this need, this paper proposes an emotional indicator framework for systematically eliciting students' recollections of potential experiential learning opportunities.

In empirically examining students' experiences in reflective focus groups that utilized the framework, we presented two examples of students' learning outcomes from reflection. The following examines more closely two critical aspects of the results that were also prominent in the wider sample of participants: (i) the reflections enabled through the triggers spanned a wide range of learning processes, and (ii) the emotions associated with the learning experiences provided an intuitive access to meaningful reflection.

(i) The two examples presented above illustrate that the experiences the students engaged with in the focus groups covered learning along a spectrum from concrete, content-, or process-oriented aspects to fundamental considerations relating to students' overall professional formation. This range mirrors the scope of the program outcomes defined by ABET<sup>34</sup>. This indicates the promise of this method of reflection to support traditional teaching of engineering content through meta-

cognitive insights and, at the same time, address some of the broader attributes that have proven problematic for traditional instructional methods<sup>35</sup>.

In the example presented in the results section, Drew outlined insights concerning the importance of early phases of project work which corresponds to program outcome [e] in<sup>36</sup> that is defined as “the ability to identify, formulate, and solve engineering problems.” This aspect would ideally be part of explicit teaching of the design process, be experienced by the students in class projects, and be consolidated through reflection as presented here.

The second quote, in contrast, grapples with fundamental issue relating, for example, to program outcome [i] that describes the “recognition of the need for and an ability to engage in life-long learning”. Such aspects of their overall learning can be presented to students but cannot be directly taught in the traditional sense. Reflection, in this context, can capitalize on learning opportunities that exist outside direct instruction and help students achieve such broader outcomes.

(ii) The reflection based on emotional indicators also does not limit the students’ reflective learning to preconceived categories. As opposed to asking students to reflect on the achievement of a particular learning outcome, this approach provides room to access any experiential learning opportunity. The student can make sense of this in the context of his or her own learning and not within the framework imposed by the educator’s preconceptions of learning outcomes<sup>29</sup>. For the assessment of these outcomes in the context of program accreditation, this very aspect holds the promise of more thoughtful collection of evidence compared to the risk of confirmation bias that is inherent to instruments that ask students directly to report on their achievement of the abstract program outcomes.

This intuitive recall of critical learning experiences also points to a possible way of addressing the need for students to ‘practice’ or ‘learn’ reflection<sup>37</sup>. It seems arguable whether repeated engagement in reflective exercises alone can achieve this goal in an ideal way. The analysis of the data presented here suggests that becoming aware of and comfortable with the critical emotion is a key aspect of the reflective learning process. In Schön’s<sup>38</sup> description, the reflective practitioner “allows himself to experience surprise, puzzlement, or confusion.” In a similar way, the emotional indicator framework offers the educator the opportunity to systematically foster students’ sensitivity to the emotional disturbances that are associated with critical learning situations. Developing such sensitivity can then enable students to become a reflective practitioner who recognizes and utilizes experiential learning opportunities in the workplace in the sense of becoming a critical professional and life-long learner.

## **Conclusion**

Based on the recognition of the critical need for reflection as a part of engineering students’ overall professional development, this paper proposed a framework of emotional indicators that can be used to elicit students’ recollection of critical learning experiences. This addresses the lack of systematic approaches to initially trigger meaningful reflection and can, at the same time, be used with existing approaches that structure reflective analysis in various formats.

The framework maps out a space of possible triggers for reflection along the dimensions of (i) the emotional indicators of **novelty, challenge, progression, exploration, and insight** and (ii) levels of concrete manifestations of these emotions in the students' learning experience.

This framework was used to facilitate reflective focus groups in an interdisciplinary, project-based course. The early analysis of the focus group data suggests that the method enabled students to intuitively identify critical learning moments from the emotions associated with them. The resulting reflections spanned a wide spectrum of student learning from concrete meta-cognitive insights to broader aspects of identity formation.

In light of these results, the discussion explored the promise of the method in supporting student learning across the full range of program outcomes, and in systematically developing learners' reflective abilities.

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