Create!: Metacognition in an interdisciplinary course

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***Abstract*—This Innovative Practice Work in Progress Paper focuses on an interdisciplinary course with the title Create! which draws in students from a range of years and disciplines to engage with ill-structured real-world problems. The study aimed to characterize students' reflective and metacognitive processes as they engaged in these team-based challenges. The data for the study came from "freewrites", which were regular assessments which required students to respond to reflective prompts. The study utilizes the IDEALS model for characterizing the stages of metacognition. Using data from six exercises, this exploratory study works with just over 75 responses to find which of the IDEALS stages were represented in student reflections and what form these took. The findings show detailed contextualized reflections across each of the IDEALS stages. The study supports the value of this team-based project-centered course structure for stimulating metacognitive reflection in an interdisciplinary context. It also confirms the validity of the IDEALS model for characterizing metacognitive processes.**

Keywords—interdisciplinary engineering education, project-centered course, metacognition, reflection

I. Introduction

Engineering education continues to hear calls for significant change. People in power such as policy makers and national leaders argue that students graduating from engineering programs must be able to contribute in the ever-changing work environment of a highly competitive global market [1]. There have been studies which show that while engineering education was found to do well in imparting knowledge, it is less effective in preparing students to integrate their knowledge with professional skills [2]. Most engineering courses at the undergraduate level are not well aligned with the interdisciplinary spaces that engineering graduates will find themselves working in. However, interdisciplinary courses provide unique challenges in evaluating individual student performance as it is often through teamwork that coursework objectives are met.

Metacognition is an important capacity for students to develop to support development of problem solving skills and the self-regulation of their learning [3]. Because students tend to focus mainly on project completion, explicit requirements for students to engage in metacognitive reflection can help them to develop professional skills which can be transferred to other settings [1].

A model, developed by Kaplan et al. called the IDEALS model of integrated learning and assessment activities builds reflection and metacognition into professional skills. The IDEALS model takes students through six steps of design Initiate, Define, Execute, Assess, Learning and Show.

The purpose of this study is to evaluate an interdisciplinary course's "freewrites", which are reflective exercises that students complete throughout the course, to evaluate which steps of the IDEALS model are shown in their freewrites. This will inform the researchers about which metacognitive practices students use while working through a team based interdisciplinary course in solving an ill-structured problem. It is worth noting that the freewrites are part of the course and were not specifically collected for this study. The research question we aim to answer is:

In an interdisciplinary course based around an ill-structured problem, what forms of reflection and metacognition do students engage in?

II. Reflection and Metacognition

Reflection and metacognition have deeply intertwined histories in discourse on teaching and learning. Generally, in learning, content and procedural knowledge alone are insufficient for persistent and self-directed growth in a learner's understanding and expertise [1]. It is through *how* one learns content or practices procedures that gives rise to the moment of reflexivity in reflection and the moment of meta in metacognition - that is, the moment of standing above or apart from oneself, in order to turn one's attention back upon one's own mental work. In broad terms, reflection is defined as a conscious exploration of one's own experiences and metacognition as the act of thinking about one's own thought processes [1].

Research in education has identified the importance of helping students develop the ability to monitor their own comprehension and make their thinking processes explicit [2] and it is of interest to this study to identify how students self-regulate their learning through reflection and metacognition. Metacognition allows students to become aware of what they are doing and when they are learning. If a student has been taught to "monitor" their writing process by inserting self-reflective comments into their work, noting when they have trouble overcoming a challenge, then they may be prompted into ways of solving this challenge. In the best case scenario,

the student may be able to overcome the challenge without the aid of an instructor, and in the realisation of solving their own problem may lead to more self-efficacy and belief in their own problem-solving skills. The student who can monitor their own progress in this way is referred to as a self-directed or self-regulated learner.

III. The IDEALS model

The Integrated Design Engineering Assessment and Learning System (IDEALS) takes the idea of metacognition and defines a set of steps that students should ideally go through, summarized in the table below:

TABLE I. STEPS IN THE IDEALS LEARNING AND ASSESSMENT MODEL

Step	Explanation of Step
Initiate	A professional challenge arises in the context of a team-based design project.
Define	Through analysis of the problem and planning, students assess the situation, define important needs, set goals, and create a plan for achieving strong performance.
Execute	Students take action, in concert with team and project goals, to implement their plan.
Assess	Students assess progress toward goals and then revise plans as needed to enhance achievements.
Learn	Students practice knowing-in-action and achieve results more characteristic of professionals.
Show	Students document their achievements in work products, skills development, and learning.

The Initiate and Define steps take students through their initial response to the problem, guided by their initial understanding of the problem. The Execute and Assess steps have students taking action in finding out how they can address the problem and test their proposed actions. The Learn and Show steps have students present preliminary findings which demonstrate their professional development skills and then implement improvements to their solutions while they learn from feedback on their presentations of their proposed solutions. These steps allow students to demonstrate knowing through action which can be transferable to new situations. The model is therefore suitable in assessing knowledge suitable in professional practice [1].

IV. Methodology

The "freewrites" in the course are regular writing assignments which aim to have students reflect on their journey throughout the course. In each freewrite students write and reflect by taking five minutes to do a journal entry. The prompt varies slightly with each freewrite, sometimes asking students to answer questions pertaining to a certain theme in class, but generally they are required to write freely and ask two questions of inquiry about what more they would like to know. A qualitative narrative analysis was performed on these assignments. The IDEALS model was used to create *a priori* codes which characterized students' reflection and metacognition as they went through the course. The first author did the first round of coding, and the validity of the categories were established by the other authors to establish reliability of the coding scheme. The aim of this analysis was to understand students' thought processes and metacognition as they went through the course.

Seventeen out of the twenty students enrolled in the course had agreed for their assignments to be used in research by filling out IRB consent forms. The majority of students are from the College of Engineering with some students having Computer Science, Life sciences and Human Sciences backgrounds. They also span a range of undergraduate years.

For the purposes of this analysis, the student responses to six freewrites were used (Table 2), each of which had slightly different prompts, except for freewrites 2 and 3, but all required students to pose two questions of inquiry. A total of 75 freewrites were analyzed. The researcher downloaded and de-identified the data which was then uploaded to a shared Google Drive folder.

TABLE II. FREEWRITE PROMPTS

	Explanation of Step
1	Consider what you learned today, or those concepts that this activity might have reinforced for you. Are there aspects of other disciplines that are interesting to you? What were some of the reasons that you chose your discipline? Which of your interests are aligned with your major?
2	Each entry should include two questions of inquiry. What more do you want to know? What are you curious about? What are the assumptions that you want to push back on? Highlight or underline the questions in your journal.
3	Each entry should include two questions of inquiry. What more do you want to know? What are you curious about? What are the assumptions that you want to push back on? Highlight or underline the questions in your journal.
4	How do you feel about contacting people out of the blue to ask them questions? Are your feelings different for experts and average people? How do these interactions affect the emotional states of the participants? How does that affect interactions?
5	What are your thoughts about the rural broadband issue from today's presentation? How do you think the government does or could influence your team's problem system?
6	How has participating in the Lerman critique process changed how you think about your own project? Did you see any changes in the way you considered other teams' projects before and after the critique?

V. Results

In the analysis of the freewrites we found evidence of each step in the IDEALS model, as shown in Table III, which indicates the number of coded extracts found in each step in each of the freewrites. Even though the IDEALS model is presented as a linear process, it is worth noting that students spent time grappling with the different steps in the ideals model as they went through the course, not necessarily in a linear fashion.

TABLE III. FREEWRITES WHERE IDEALS STEPS WERE IDENTIFIED

Step	**Freewrite No.**						**Total**
	1	**2**	**3**	**4**	**5**	**6**	
Initiate	0	4	0	0	0	0	4
Define	0	4	0	0	0	1	5
Execute	0	1	1	1	0	0	3
Assess	2	0	1	1	1	1	7
Learn	0	0	3	0	0	2	5
Show	0	0	2	0	0	4	6
Total	2	9	7	2	1	8	30

Table IV shows an exemplar of a coded extract for each of the IDEALS steps.

TABLE IV. EXEMPLARS OF CODED DATA (THE "CODEBOOK")

Code	Description	Example
Initiate	A professional (e.g, teamwork, self-directed learning, or professional/ethical) challenge arises in the context of a team-based design project; this delays progress or limits performance and calls for assessment.	3S21 Freewrite 2: "One other ailment regarding this project is the scope of the project. Quite frankly, I'm not even sure of the direction our project is supposed to take outside of "be related to health".
Define	Through analysis of the problem and planning, students assess the situation, define important needs, set goals, and create a plan for achieving strong performance	2S21 Freewrite 2: "Using keywords and more advanced searches we can easily find the resources we need to further our understanding on our topic."
Execute	Students take action, in concert with team and project goals, to implement their plan for achievement of the process and high-quality work products.	4S21 Freewrite 4: "I think that it is very important for our project especially that we go out of our way to gather as much data as we can. With covid and the fact that all the correspondence is going to be through a screen makes it a lot easier to do"
Assess	Students self-assess, peer-assess, or jointly assess progress toward goals and then revise plans as needed to enhance achievements	2S21 Freewrite 4: "Me and my group are aiming to ask more deep and personal questions, so we are not sure how the people are going to react. Are they going to open up and talk to us or shut us out?"
Learn	As students implement their plans and think reflectively and metacognitively, they practice knowing-in-action and achieve results more characteristic of professionals.	15S21 Freewrite 3: "While digging deeper I noticed that everyone feels differently about their exact needs for what they might want out of a product. Then it was clear to me the purpose of what we were doing as careful details about a customer's needs would definitely need to be noted when trying to solve their problem, design a product to sell to them, etc."
Show	Students document(show, explain, extend) their achievements in the work products, skills development and learning.	17S21 Freewrite 3: "Multiple designs were presented to our "customer" and we received feedback on what they liked and disliked. "

A. Initiate

In the *Create!* course the teams were given an interdisciplinary context for focus and given free range to decide how they were going to go about tackling a problem in this context. The contexts under examination were: Health, Food, Technology, Finance and Sports. In-class activities required students to use *Coggle* to generate mind-maps about their topic areas to evaluate how they could find a problem within these areas and explore it, and eventually come up with a potential solution to the problem they have identified.

The biggest challenge many of the teams grappled with was which direction to go in and many of them expressed confusion as the topic areas were so broad. These reflections were often coded in this category *Initiate*, for example:

1S21 Freewrite 2: "Our group is now considering talking about dissemination in sports and the different ways it might manifest itself. One issue is that this seems to not really lend itself to finding very academic sources through the methods that we learned today. Does this mean that maybe we should lean towards a more academically researchable problem?"

This student shows that they have prior knowledge of the topic and speak about how they are grappling with using this knowledge to tackle the problem. Since this is the initial step in the process it can be seen that they are speaking broadly about the problem presented and starting to plan a scope for how they will tackle this problem.

B. Define

Looking at the freewrites for indicators of defining the problem we can see that students begin to ask questions about how to scope the problem and what falls in the category of their particular problem area, for example:

6S21 Freewrite 2: " I'm curious how in-depth we are going to go into the problem space that we are researching as a group, I think our topic is going to be something I have talked about a lot both in college and just with my friends, so how much more can I learn about it? I'm not sure if I'm pushing my group too hard to go in the direction I want to go, are we going on the topic we are mostly because of me or does everyone have a genuine interest in it?"

Student 6S21 is considering how in depth they will go and also speak about their position as someone who has spoken about the problem before in informal conversations with their friends. They are also recognising their own biases in trying to push a certain topic's direction while also being mindful of the group and which direction they would like to go with the problem.

C. Execute

The *Execute* step is described as when students take action with their teams to achieve the project goals. Different aspects of the class instruction are aimed to assist students in the process of undergoing their execution, but they were encouraged to choose the route that best fitted the area they were exploring, for example as shown in this extract:

3S21 Freewrite 3: "Following these interviews, we developed an action statement as well as the customers wants and needs. Ultimately, the cycle of design, customer review, and revision was a very enjoyable process. "

This student has spoken about their data collection protocol and the importance of how they are going to execute it. It is worth noting that the overlapping of the different stages of the IDEALS model made it somewhat difficult to clearly place what was being said in each. Many groups spoke about how they were going to use interviews with stakeholders to gather data and one other spoke about *"gathering as much data as we can"*. It can also be seen from Student 3S21 that they spoke about the cycle of design and reviewing which encompasses many aspects of the IDEALS model, not necessarily just the *Execute* step alone.

D. Assess

The *Assess* step was seen across many of the different freewrites. In this step students reflected on how they were progressing towards their goals and how they undergo the process of researching their problem areas in other ways as can be seen by Student 2S21's reflection of how they could refine their interview process:

2S21 Freewrite 4: "Me and my group are aiming to ask more deep and personal questions, so we are not sure how the people are going to react. Are they going to open up and talk to us or shut us out?"

Student 7S21 also displays an assessment of their process by indicating that they felt they were heading in the right direction with solving the problem.

7S21 Freewrite 6: "However, the process overall made me confident that we are on the right track for success and the project is going pretty well. Before this, I thought we were going down a deep hole of failure"

E. Learn

At this stage many students had presented some of their findings to the class and were able to get feedback on potential improvements they could make to their current process. This prompted learning, for example in this extract:

15S21 Freewrite 3: "While digging deeper I noticed that everyone feels differently about their exact needs for what they might want out of a product. Then it was clear to me the purpose of what we were doing as careful details about a customer's needs would definitely need to be noted when trying to solve their problem, design a product to sell to them, etc."

This student has expressed how various stakeholders have different needs and how further clarity was achieved through their presentation and the feedback provided by their peers.

F. Show

The final step in the IDEALS model is the *Show* step which was illustrated mostly in freewrite 6. This was a stage where the groups presented their findings and achievements in the solutions they began to form.

While presenting, many teams received feedback which enlightened them to look at other avenues on how to complete their projects. Student 6S21 expressed how helpful it was to present and receive feedback on how to move forward with completing their project and how observing and critiquing other presentations offered them insights into their own projects:

6S21 Freewrite 6: " The critique that my team received was great! Many people helped our team move forward after our presentation and even helped us clarify for the group/project on where we are heading as we wrap up our project."

In the reflections coded in this step we were also pleased to see evidence of how students were able to critically view other teams' presentations and how they were actively participating in providing feedback to their peers while also using this knowledge to further their thinking about their own work, for example:

4S21 Freewrite 6: " I looked at a few of the other teams projects differently after their presentations presented their problem very clearly but I also came to understand more things about their projects just from the questions and comments the audience had"

VI. DISCUSSION

The analysis of the "freewrites" in this interdisciplinary course has shown evidence of how this course structure prompts students to engage in all stages of the metacognitive process as represented in the IDEALS model. The biggest challenge many of the teams grappled with was which direction to go in and many of them expressed confusion as the topic areas were so broad. It is part of the process of ideating to have divergent thinking and making sure that as much of the scope of the issue is explored as possible, and metacognitive thinking is essential for accomplishing this.

In looking across the freewrites we noted (as per the counts in Table III above) that freewrites 1, 4 and 5 showed relatively low counts for steps in the IDEALS model and this might be because these prompts were not directly related to the project the students were working on. While this confirms that the project itself was a good prompt for IDEALS type thinking, we also saw that students also used the freewrite assignments to write about other aspects of their lives which can be seen as indicators of metacognition, but not related to the IDEALS model.

VII. CONCLUSION

This analysis has demonstrated the value of the IDEALS model for characterizing students' metacognitive processes in the context of an interdisciplinary and experiential team-based course. This supports its future pedagogical value for making these processes explicit. A further benefit of this study has been to confirm the value of the freewrites assessment exercises in the course; showing that students used these to engage in productive reflections.

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