Reflection in Engineering Design: Student Perceptions on Usefulness

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Abstract

Reflection in engineering design promotes the development of personal and professional skills, helping students to document the steps they took, examine the outcomes, and looking ahead to the following weeks. This reflective practice contributes to adopting a growth mindset and becoming life-long learners. In a study of 1,278 reflections of 83 second-year engineering students over two years, this paper is an exploratory examination of the act of reflecting in a two-semester engineering design course. Reviewing an end-of-year survey on the act of reflecting as well as the reflections themselves, this study presents student perceptions of reflections and whether the reflections changed throughout the design process. We found that 55% of participants describe reflections as useful, and 78% of participants describe the reflections as impacting their design project, team dynamics, or personal development. Seven themes are documented about student perceptions of reflections, including: expansive thinking, examining the project more deeply, team dynamics, goal-setting, looking back at progress, planning next steps, and functional critiques. We also found that the number of words for each reflection changes with the design process.

Introduction

Adopting a self-reflective practice promotes critical thinking and develops meta-cognition to allow practitioners to become aware of their thoughts and patterns of thinking[1]. Essentially, reflection promotes the action of thinking about one's thinking [2]. It is the core of life-long learning [3], which is identified as an essential attribute of an engineer [4]. In order to practice life-long learning, a person must be able to identify their deficits and make a plan to acquire the missing knowledge or skills. The awareness that comes with the practice of reflection enables the person to realistically and bravely assess their gaps for continued growth [5]. The adoption of a growth-mindset also develops resiliency and persistence, understanding setbacks as opportunities for growth, not failures.

Developing a reflective habit in the engineering design classroom can help students realize these benefits. Pragmatically, reflection assignments create an opportunity for students to review the steps they took and to make plans for how to proceed [6]. In addition to producing a design, the aims of design courses also includes developing personal and professional skills, such creativity, communication, and program management skills. Documented through previous research [6–9], developing a reflective practice aids the acquisition of design skills, either directly or indirectly. For example, goal setting within reflection directly exercises students' program management skills. Also, students can examine team dynamics [10,11] and their personal leadership style in the reflections, encouraging them to directly focus on their interpersonal skills and communication. Indirectly, reflection on the design project itself encourages students to reexamine the problem, to find more creative solutions and broaden their thinking. Though reflection can indirectly support numerous learning outcomes, a 2022 study of over 3,000 first-

year students engaged in reflection suggested that reflections with "limited number of purposes or clear learning goals" will have better outcomes, supporting earlier research by Aronson [5,12]. Thus, design instructors are encouraged to target particular learning outcomes for students to focus on in their reflections.

Service learning projects, where the project centers on a user or community partner [13], are one type of project where reflection plays an essential component of helping students consider the impact of their designs on those who will be impacted by their work [14]. There is a tendency in engineering to focus more on the design than the people who require it [15]. This can be called being thing-focused instead of people-focused [15]. Service-learning and its reflective practice through targeted reflection prompts helps students to resist this tendency and encourages students to consider the people in the project, instead of the thing (device) that they are designing. However, and fundamentally, the authors have seen the benefit of reflection in other learning experiences, and its application should not be limited to service-learning projects, but incorporated more broadly across a design program.

In their year-long, second-year design course, Sustainable Design Engineering students at the University of Prince Edward Island work in teams with community partners from public, private, and non-profit sectors. Each team has a different design project, and each student performs weekly reflections during the fall semester and bi-weekly reflections during the winter semester. In the 2021–2022 and 2022–2023 academic years, students also completed a survey at the end of the year to provide feedback on the act of reflecting and were invited to participate in a study reviewed by the institution's Research Ethics Board. This paper is part of a larger study on being thing-focused versus people-focused within design education. The subject of this paper is on the reflections themselves, adopting the Aronson advice to "reflect on the process of teaching reflection" [12]. The two research questions for this paper are as follows:

I. Do students perceive reflections as useful?
II. Does the act of reflecting change throughout the design process?

This is an exploratory examination of 1,278 reflections that were recorded during these two years of design projects.

Background Information

Land Acknowledgement and Positionality Statements

In order to understand the context in which this paper was written, we offer the following land acknowledgement and individual positionality statements. First, we acknowledge, respect, and are grateful to live, work, and learn in Epekwitk, Mi'kma'ki, the traditional, unceded, and unsurrendered lands of the Mi'kmaq people.

Next, both authors are of European descent, and one identifies as a woman and the other a man. Libby is a self-professed life-long learner and practitioner of daily reflection, and she encourages students to develop a growth mindset through her second-year design courses. Christopher teaches inclusive and accessible design of interactive systems and uses reflection to help students consider different lenses through which to consider their design choices.

Pedagogical Use of Reflection in Design Course

During the fall and winter design courses, students complete two design projects. Project 1 is typically a service-learning 5-week project with a community partner from the public sector. All teams of 3–4 students work on the same objective. The 2021–2022 project objective was to improve the energy efficiency of a community center, and the 2022–2023 project was to design a green wall for the City. In both projects, students met with the community partner, and went through the design process that was appropriate for each project, as shown in Figure 1. During this time, students completed weekly reflections. However, due to a hurricane and massive power loss, the 2022 year had two fewer reflections in Project 1. The asterisks in the figure denote that a reflection was planned but removed through course co-creation and redesign with the students during the semester.

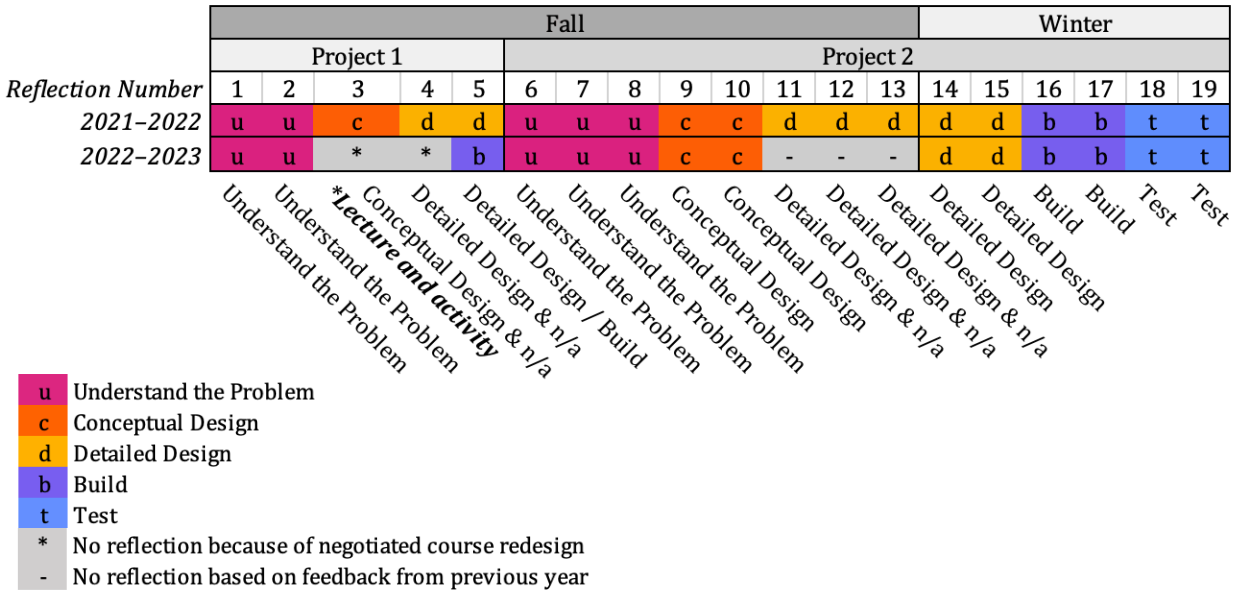


Figure 1. Schedule of design process, projects, and reflection.

In contrast, Project 2 began in week 6 of the fall semester. Students ranked their preferred projects from descriptions of the 12 community partners and design challenges. Applying knowledge gained during the first project on team dynamics, work ethic, quality of assignments, and communication ability, instructors created teams. While prioritizing student preference, teams were optimized to ensure each team had a mixture of skills in CAD, technical writing, building, and analysis, to ensure a positive outcome for the community partner. Each team had a unique design challenge with a community partner from industry, non-profit organizations, or government.

Reflections occurred weekly through the fall semester and bi-weekly during the winter semester. Incorporating feedback from the 2021 year to the 2022 year, the number of planned reflections was reduced from 13 to 10 to align better with the design schedule (identified as dashes in Figure 1). Coupled with the hurricane, the number of fall reflections for 2022 was only 8, less than the anticipated 10.

Early during the fall semester, in week 3, students participated in a short lecture and interactive activity to understand the benefit of reflection. Working in pairs, one student who is blindfolded completed a maze on paper while being directed by the other student who was allowed to speak during the first round, then was muted in the second round. Students reflected in between rounds by answering three questions:

- *What* happened? How did it go? What was good about it? What was bad about it?
- *Why* did it happen?
- *What* would you do differently?

Once they practiced reflecting a few times, students received a short lecture on reflection to understand how it is related to design. They then submitted a final reflection on the maze activity and were encouraged to focus on the third question.

Pedagogically, reflections were intended to be a formative learning experience, so collectively, they were only worth 4% of the overall mark. Reflections were graded out of 3, and students received full marks if they demonstrated critical thinking, moving through *what happened*, to *why did it happen*, and lastly to *what will I do differently*? Essentially, a 3/3 meant "good depth" and a lower score encouraged students to think deeper.

Reflections were completed online, using Microsoft forms, and students could opt for their responses to be emailed to them. An online form was selected instead of electronic pdf submissions for faster review and to differentiate the type of assignment from the more formal weekly technical reports. The following prompt was communicated on the learning management system (Moodle) as the reflection assignment for each week:

> *Research has shown that the ability to think critically and develop your ability for metacognition - to think about your thinking - can increase your capacity and rate of learning. Additionally, you can go back through the project to see how your thinking developed.*
>
> *Spend between 15 minutes and 30 minutes to reflect on this week's activities. (Set a timer). Complete the activity online at this link.*
>
> *Reflections scored 0 to 3 for quality and complexity of critical thinking (basically, on effort).*

To encourage students to reflect quickly and intensely, they were asked to record the start and stop times for the reflection. Additionally, given the low-weighting of the assignment, the large number of assignments in the design course, and the perfectionistic tendencies of some students, the time limit provided immediate feedback and encouragement to be more efficient and not

belabor the assignment. The online form also recorded start and stop times for comparison. The reflection questions are as follows:

1. What time is it now?
2. Define the Problem (for the Project/Community Partner - As you understand it, what is the problem you are trying to solve? It may not seem like it changes each week, but your understanding of it will evolve).
3. Describe your Proposed Solution. (for whatever stage is appropriate at this time).
4. In 1 or 2 sentences, summarize what steps you took this week.
5. Answer any of the following (include the letter(s) of the question(s)) - do not exceed 30 minutes:
    a. What did you learn about the problem this week?
    b. How did the solution evolve?
    c. What steps did you perform this week?
    d. What went well?
    e. What didn't go well?
    f. What could you have done so it turned out better?
    g. Where there any limitations you encountered this week?
6. What do you plan to do next week?
7. What time is it now?

While four of the content questions were the same each week, the fifth question provided variation and probed for deeper reflection. At the end of each semester, additional questions relating to individual performance and team dynamics were added.

Method

After the final reflection was submitted, students were provided with an end-of-year survey on reflections and invited to participate in this research study, following a protocol approved by the Research Ethics Board at UPEI. Of the 96 students, 83 students elected to participate, providing an 86% response rate. There was a balanced representation from the two years of data collection, with 41 participants from 2021–2022 and 42 from 2022–2023. Similarly the sample was representative of the class in gender identity, as 4% of the participant group identified as non-binary, 29% as female, and 67% as male. Data were not collected on ethnicity or nationality.

The end-of year survey contained nine items, seven of which are outside the scope of this paper as they relate to the larger study on people-focus or thing-focus. Only two items are pertinent to this paper on the act of performing reflections:

1. Compared to other assignments, did you enjoy performing the reflections more or less (on a 5-point Likert scale: much less, less, about the same, more, much more). Explain. (free response)
2. Did reflections affect your design project? (free response)

Enjoyment was recorded on a 5-point scale from the Likert portion of the first item (bullet above) comparing the act of reflecting to other assignments. The qualitative data (free responses) from the two bulleted items above were reviewed together, qualitatively coded, and converted into two quantitative items: *impact* and *usefulness*. *Impact* was created as a 3-point categorical

interpretation of the second item on whether reflections affected the design project (no, contradictory information, yes).

Usefulness adjusted the 5-point *enjoyment* score to a 4-point scale based on the qualitative information from the two items: never useful, rarely useful, sometimes useful, and useful. A 4-point scale was used instead of 5-point because "mostly useful" and "very useful" felt like arbitrary distinctions, so *enjoyment* scores of 4 and 5 were combined to be *usefulness* scores of 4. If participants were asked this question directly, a 5-point Likert scale would have been appropriate. However, because it was assessed and assigned, combining "mostly" and "very" seemed more meaningful than trying to identify this from responses.

Values were recorded for the word count, amount of time spent in each reflection, and the percentage of reflections completed for each participant. Data were reviewed and cleaned. Any times over 45 minutes were recorded as 45 minutes, as the participants indicated they were multi-tasking. The mean word count was calculated for each participant, as well as the mean word count for reflections in project 1, project 2, and during each stage of the design process. Mean values were similarly computed for time spent reflecting.

Data were primarily analyzed using descriptive statistics, but inferential statistics are noted in the results. For parametric data, t-tests were used for 2-point independent variables and Analysis of variance (Anova) tests were used for 3-point or larger independent variables. For non-parametric data, Mann-Whitney and Kruskal-Wallis tests were employed for 2-point and 3-point or higher dependent variables, respectively.

Results

I. Do Students Perceive Reflections as Useful?

In short, 55% of participants described reflections as being useful, as one participant explained, "Technical writing is an important skill, but the ability to recall my thought process…is much more vital." Conversely, 15% of participants felt reflections were rarely or never useful and 30% were ambivalent and categorized as "sometimes useful", as one participant wrote, "While I see why they're needed, they felt tedious and repetitive." The frequencies of the 4-point scale are shown in Table 1.

Table 1. Perceived usefulness, enjoyment, and impact of reflections.

	Usefulness n (%)
Never useful	5 (6%)
Rarely useful	7 (9%)
Sometimes useful	25 (30%)
Useful	46 (55%)

	Enjoyment n (%)
Much less	5 (6%)
Less	21 (25%)
About same	33 (40%)
More	16 (19%)
Much more	8 (10%)

	Impact n (%)
No	18 (22%)
Contradictory	26 (32%)
Yes	38 (46%)

Note that this measure of usefulness was assessed from the two items on *enjoyment* and *impact.* For example, one participant described for *enjoyment*, "The reflection as in process was enjoyable, but typing it out was annoying. I think faster than I type. So some of this thoughts or the chain of thoughts was interrupted." While this participant selected "less" for *enjoyment,* they

were coded “useful” for *usefulness*, because when asked whether the reflections affected the design project (*impact*), they replied, “Yes. They affected the project by keeping me on track and challenged me to think further. They didn't have much effect on quality of my design.” For *enjoyment,* when asked whether they enjoyed doing the reflections more or less than other design assignments, 29% of participants indicated that they enjoyed the reflections more, also shown in Table 1. One participant described, “The reflections felt much lower stress than other assignments in that there was more or less no wrong answer.” Another described, “I enjoy expressing my thoughts and opinions.” Alternatively, 26% of participants enjoyed the reflections less than other assignments, explaining a feeling of uncertainty, “I sometimes felt I didn't have an answer for some of the things asked in the reflections depending on the week.” Another participant found critical reflection more difficult, explaining, “It's harder to express about what was done afterwards and what I learned about it than to just learn something.” Lastly, 40% of participants enjoyed the assignments as much as other assignments, describing “I don't like writing. However, I liked that it made me think about the things that I was doing. If given the choice, I would not have completed them but I'm glad it was required.”

When asked whether the reflections affected their design project (*impact),* 46% of participants replied affirmatively, citing benefits related to their personal development, their team, and their design. Next, 22% of participants definitively replied “no.” A third category became apparent, representing 32% of participants, who replied that the reflections didn’t impact their project, but then they provided additional information that suggested that it did have an effect. For example, one participant explained, “I do not feel like the reflections affected my design project. Only my own accountability. Reflecting on my work throughout the week allowed me to hold myself accountable to my own time management and amount of effort put into the assignments. They did not alter the trajectory of the project in any way.” This third category of participants indicates there are different interpretations of what affects the design project. From a course instructor perspective, the design project is impacted by the students, teams, and device themselves. For participants in this third category, the design process, team dynamics, and individual student development are separate from the overall design project. For example, one participant explained, “I wouldn't say they affected the project itself, but it may have made me more aware of what I need to do better in the coming weeks. And how to move the group and work along in a useful manner.” This participant identified leadership, teamwork, accountability, and goal-setting as impacts of reflection, but they saw these attributes as unrelated to the design project.

Looking across the two qualitative items, seven themes about the usefulness of reflections were identified and are shown in Table 2. The percentages represent the number of participants who volunteered this information as participants were not asked directly about these themes.

First, 13% of participants described how reflections enabled them to perform expansive thinking, to broaden their view on their project, and to engage in ongoing brainstorming. One participant stated that reflecting “helps my brain to keep finding solutions to the design” and another explained, “Yes, they allowed for more critical thinking. I found sometimes I would think of an idea during my reflections.” However, one participant (not included in the 13% statistic) directly negated this theme, stating, “The reflection is for what we already know, and it doesn't bring new ideas.”

Second, reflections provide intentional time to examine the project and understand the concepts

more deeply. As one participant identified, “I found that they helped with understanding the material and the processes that we were doing.” These opportunities to examine both the problem and the solution were mentioned by 13% of participants.

Table 2. Reflection usefulness.

Theme	*Excerpts*	*Num Participants*
Expansive thinking, ongoing brainstorming	“The reflections helped my design project by allowing me to take a step back and think about the essence of the problem/ solutions. It can be difficult to envision the bigger picture as opposed to a singular solution and the reflections guided that thinking.” “Thinking to formulate a sentence about the last couple of weeks progress helped me come up with new ideas”	11 (13%)
Examine project more deeply	“They solidified our understanding of the problem and solution.” “Highlighted problems within the group or project that I may not have picked up on otherwise.”	11 (13%)
Team dynamics & playground to work through problems	“It helped to think of what could be improved in the design as well as the teamwork.” “It was a space to openly think and talk about my project while being allowed and even encouraged to discuss what's going wrong.”	12 (14%)
Goal setting, personal improvement	“Yes, I was able to identify my strengths and weaknesses.” “I made a habit of setting realistic goals every time I completed a reflection, such as ‘stepping up more as a leader’”	29 (35%)
See progress, personal accountability	“Reflections help me understand what's going on in the project and what I actually did rather than what I think I did in the previous weeks.” “They were helpful to see the progression of the project and to evaluate personal contributions as well. The ‘what have you personally done this week’ and ‘what do you personally want to do differently next week?’”	38 (46%)
Plan ahead	“Reflections help me focus on my weekly goals for the design project.” “They were helpful in planning out the steps to take in the following weeks so they may have contributed to the efficiency of my project.”	35 (42%)
Functional critiques	“The reflections were too repetitive. I did find some questions very helpful, but there were weeks when my problem statement didn't change and it was a bit annoying to have to write it.” “They were easy, but felt long and unnecessary.” “They are quick and good for grades.”	33 (40%)

Third, 14% of participants discussed team-related impacts, such as providing opportunities to consider team dynamics. One participant described how the reflections “make me think about how I interact with my team, how I can work better with my team, or pushing them to do more.” Reflections provide a playground space to struggle with issues and examine what did and did not go well, whether with teamwork or the design project. As one participant described “I think it had some impact on how I approached both the project and my team after analyzing what did not work.”

Fourth, more than a third of the participants (35%) volunteered that goal-setting and personal improvement are outcomes of reflection. A participant plainly explained, “It also worked great to identify strengths and areas for improvement both personally and as a group.” A second participant describes gaining perspective, stating, “I find it easy to get tunnel visioned and lost in the schoolwork, so I found it invaluable to take a step back and look at what I've done, where I'm at and what is to come.” Personal goal-setting and being introspective contribute towards a growth mindset, that is crucial for life-long learning.

Over 66% of participants described the usefulness of reflections for looking back at their progress and/or planning ahead, the fifth and sixth themes. As exemplified in the following participant response, 20% of participants mention both, “The reflections allowed me to summarize my progress both personal & in relation to the design project. This made it easier to find the next step.”

The fifth theme is to see the progress and take personal accountability, as described by 45% of participants. By describing the individual actions that they took that week, students are forced to examine their actual actions, which can be a reality check if they felt they were more productive. For example, one participant found reflections “annoying if you had not as much as you were hoping to that week.” Participants noted how reflections provided an overview of the progress, such as, “It helped me keep track of what I had done earlier and what to do now, and see the progression of the design.” In the team environment, reflections highlight personal accountability to ensure each student is individually contributing, as one participant explained, “Reflecting on my work throughout the week allowed me to hold myself accountable to my own time management and amount of effort put into the assignments.” One participant sees this as a way to re-engage with the project and a source of motivation, explaining, “The reflections do ensure students reflect on their contributions and work. they have done for the project, which may increase motivation to be more involved in the project.”

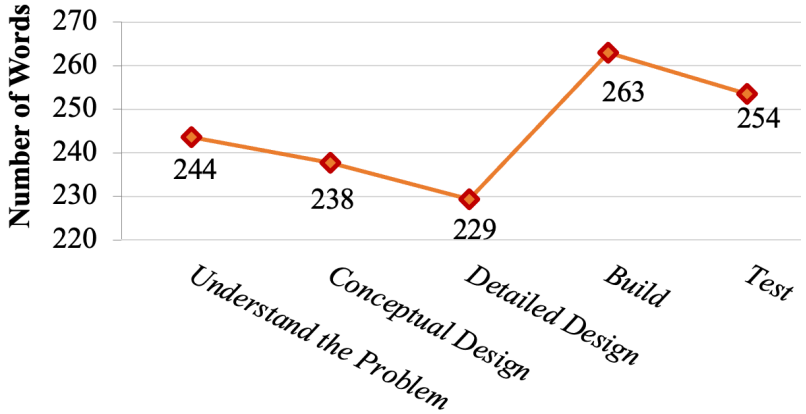
Sixth, 43% of participants mentioned the value of reflections for planning ahead, for example, “I would say they may have helped organize myself for the following week a little better.” Different from the fourth theme of goal setting, this theme represents organizational skills and planning for the next stage of the design process. In many courses, students can passively participate and be receptive to what is fed to them each week. In design, they set the pace for the completion of the project, and reflections are project management tools. As one participant described, “Yes, they helped me visualize better the things I needed to work on during the week. Facilitated having short-term goals for my project.

The seventh theme concerns the functional elements of the reflections, such as the amount of time to complete, the frequency, or the questions being asked. Containing both positive and negative perceptions of the usefulness of reflections, 39% of participants discussed these pedagogical aspects of the reflections. Interestingly, 10 participants (12%) described how fast and easy they found the reflections to be, while 3 participants (4%) found them long or cumbersome to type. An additional 24% felt the questions were too repetitive or the reflections themselves were too frequent. One participant strongly stated, "The repetition makes me feel like I'm losing my mind. The amount of times I had to type out the same sentence is over and over again is what led me to avoid doing them at points." Some participants provided constructive feedback, such as, "having them less frequently would have been more beneficial, because the answers would be more different."

A final measure of usefulness is the completion rate. Despite being worth only 4% of their overall grade, 52% of participants completed all of the reflections, 20% missed one reflection, and 17% missed two reflections. Only 11% (10 participants) did not submit three or more reflections. In their qualitative responses, 5% of participants mentioned that they forgot to complete the assignments given their large workload, the low marks, or because they wanted to complete other work before performing the reflection, as one participant described, "I often found I forgot to do the reflections due to wanting to do them after my other work for the week was done." Comparing the completion rate based on gender, there were statistically significant differences ($U = 846.5$, $p<.05$, $r = 0.26$) between male participants (M_{MALE}=92%, n=56) and female participants (M_{FEMALE}=97%, n=24). Non-binary participants completed a mean of 98% of reflections (n=3), though it was not possible to perform an inferential analysis due to the small sample size. Overall, the mean completion rate was 94%, which indicates that participants (through their actions) perceived reflections as useful enough to spend time on, despite being allotted a few marks.

II. Does the Act of Reflecting Change Throughout the Design Process?

Independent one-way ANOVA showed a significant effect between the stage in the design process and the number of words ($F(4,1273)=2.956$, $p< .05$). Figure 2 shows the mean number of words of each reflection at each phase of the design process.



Phase	Mean (SD)	n
Understand the Problem	244 (116)	405
Conceptual Design	238 (111)	186
Detailed Design	229 (106)	344
Build	263 (125)	194
Test	255 (145)	149

Figure 2. Mean number of words per reflection at each stage of design process.

Participants typically spent between 15 and 20 minutes on each reflection, which is 200–280 words in length, as shown in Table 3. It is noteworthy that the build phase had the highest number of words, but the time was not increased.

Table 3. Descriptive statistics.

		Number of Words			***Time Spent in minutes***			***Stage in Design Process***
		n	*Mean (SD)*	*Range*	*n*	*Mean (SD)*	*Range*	*2021–2022 / 2022–2023*
	Total	83	243 (86)	[81, 542]	83	18.3 (5.5)	[5, 34]	
	Project 1	83	260 (93)	[88, 522]	83	17.8 (6.2)	[6, 37]	*(Weeks 1 – 5)*
	Project 2	83	237 (92)	[63, 547]	83	18.4 (5.8)	[5, 35]	*(Weeks 6 – 19)*
Fall Semester	Week 1	83	282 (119)	[82, 599]	83	19.9 (9.0)	[0, 45]	Understand the problem
	Week 2	81	284 (120)	[72, 703]	81	18.9 (8.7)	[4, 45]	Understand the problem
	Week 3	37	242 (98)	[70, 458]	37	19.4 (9.8)	[4, 40]	Conceptual design / none
	Week 4	36	248 (105)	[68, 493]	36	16.5 (7.4)	[5, 35]	Detailed design / none
	Week 5	68	235 (119)	[35, 690]	68	15.2 (9.5)	[3, 45]	Detailed design / Build
	Week 6	79	207 (109)	[42, 560]	79	19.5 (10.4)	[5, 45]	Understand the problem
	Week 7	83	221 (107)	[69, 540]	83	16.7 (8.4)	[2, 45]	Understand the problem
	Week 8	79	223 (99)	[46, 527]	79	15.5 (8.3)	[0, 45]	Understand the problem
	Week 9	74	235 (104)	[53, 482]	74	15.5 (9.0)	[3, 45]	Conceptual design
	Week 10	75	239 (123)	[39, 732]	75	16.2 (8.1)	[3, 45]	Conceptual design
	Week 11	38	211 (99)	[49, 466]	38	16.9 (9.6)	[0, 45]	Detailed design / none
	Week 12	38	207 (100)	[92, 501]	38	16.7 (9.0)	[1, 45]	Detailed design / none
	Week 13	36	198 (95)	[93, 536]	36	27.8 (12.9)	[6, 45]	Detailed design / none
Winter Semester	Week 14	80	244 (116)	[51, 602]	80	17.2 (9.0)	[0, 45]	Detailed design
	Week 15	80	255 (107)	[84, 689]	80	19.3 (10.5)	[5, 45]	Detailed design
	Week 16	81	247 (114)	[47, 603]	81	18.7 (10.5)	[3, 45]	Build
	Week 17	81	274 (130)	[85, 849]	81	18.2 (8.4)	[5, 45]	Build
	Week 18	71	277 (155)	[115, 925]	71	17.3 (10.3)	[2, 45]	Test
	Week 19	78	232 (133)	[46, 765]	78	29.0 (14.0)	[0, 45]	Test

Looking across the design process, participants preferred having more frequent reflections earlier in the process as compared to later in the process. One participant explained, “The reflections were useful when it came to exploring concepts, yet not fully understood. However, once a direction had been selected, they were very repetitive.” One participant even noted an understanding for why reflections were more frequent early in the design process. They said, “When they switched from weakly to biweekly, I thought that was a great change. Although we were doing many more different things first semester when it was weekly, which makes sense.”

Discussion

It is affirming, from a pedagogical standpoint, to see that 78% of participants describe the reflections as impacting their design project, team dynamics, or personal development. Further support for incorporating reflections in design is that only 15% of participants describe

reflections as never useful or rarely useful. The participants' thoughtful responses to the end-of-year survey produced six benefits of reflections and a series of critiques about the pedagogical practice of doing reflections.

The repetitive nature of reflections was the most criticized element, particularly the first question to restate the problem statement. If this question were only required for the early stages of the design process, student satisfaction would likely increase.

The following recommendations for use of reflections in design projects are derived from the participant feedback:

- Set a time limit, as "The time limit made the reflections feel like less of a burden."
- Assign only a few marks to ensure reflections are "low stakes."
- Change the frequency of the reflections to be more often early in the design process.
- Tailor the reflection questions to the stage of the design process, reducing repetitiveness.
- Ask the "looking back" and "planning ahead" questions each week.
- Sporadically include questions to examine personal accountability and goal setting.
- Encourage ongoing brainstorming and ideation later in the design process.

Perhaps the most interesting finding is from the *impact,* in realizing that at least 32% of participants do not see personal development, project management, or team dynamics as impacting the design. Their view of the design is narrowly-thing focused, and they do not recognize the process of designing as connected to the design. Nor do they see the well-being or development of the designers as impactful to the design. Perhaps revising the wording of the question would produce different results, or this could be probed further in future studies, particularly to compare whether fourth-year students have the same perceptions. It also suggests that there is merit in the larger study to examine whether the participants are people-focused or thing-focused.

Lastly, one of the hardest parts of assessing design courses is being able to identify what work each student performed, to determine whether they share in the group effort. Reflections can aid in documenting the actual work completed by each student and help them to recognize their personal accountability towards the team effort. Though reflections were occasionally used to vent frustration about teammates, they can be beneficial to keep the focus on the individual student. One student explained, "I wish they were shared with the group so we could see how everyone was doing." An optimistic interpretation of this request could be to encourage students to share a portion of their reflection in an ongoing project management exercise, or perhaps the goals that they set for that week. After the initial instruction on reflections, ongoing development could occur by connecting the reflections to other topics throughout the year. For example, coupling project management with reflections as tools could facilitate better team goal setting.

Limitations

As with any long-term study, there are areas that may impact the validity of the results. Internal validity was threatened by two major events. First, was a hurricane in the fall of 2022, which interrupted study for a short period of time and the reconfiguration of courses meant that some reflections were lost. While not ideal, the loss was small, and given the strength and consistency

of many of the themes across the two years, we feel that it did not impact the results in a major way.

Second, in the winter of 2023 there was a faculty strike. From examining the data and the consistency of results, we believe that the impact was minimal. Not only were the qualitative results relatively consistent within each individual's reflections but work steadily continued on most projects during that strike period with groups working with community partners. Also, the number of reflections was not impacted by the strike, but the strike could have impacted the return rate, leading to some data loss.

In terms of external validity, this study was undertaken at a single university. This potentially limits some of the generalizability of the results. However, due to a substantial international student population in the faculty in which the study took place (approximately 40%) and the involvement of a large amount of community partners, many of these results are likely to hold in other settings.

Finally, the end of semester reflections included additional team dynamics questions, which would impact the time of the reflection. However, the word count is computed for the same questions each week and might be impacted with fewer words to account for taking time for the longer survey but is not apparent in the results.

Conclusion

In this 2-year study, the research team sought to answer two key questions regarding the use of reflections in teaching of design to engineering students. In particular, the study explored what aspects of reflections students find useful, and how the design process was influenced, so that reflections can be more successfully integrated in to design.

By studying the reflections submitted by students across their projects and end of project questionnaires regarding their experiences, there are several important reflections regarding our own teaching. In particular, substantial numbers of students identified that reflections helped them to set goals in their design projects, see their progress, and take personal accountability in their work.

From the reflections of students on the act of reflecting, this work has provided a set of recommendations on how reflections can be improved in the practice of teaching and learning. These lessons will not only help those at the institution where the study took place, but also are broadly applicable to many different types of design tasks and settings.

Most importantly, 78 out of 83 participants in this study (94%) identified reflections as useful, and through their reflections we can see them engaging in critical thinking and meta-cognition regarding their own practice. These are all marks of thoughtful design that will serve the students well whether they are working in engineering settings or in their day to day lives.

References

[1] X. Xu, L. C. Bland, S. M. Kusano, A. Johri, "The development of engineering students' metacognitive skills in informal engineering learning activities," in *Am. Soc. Eng. Educ.*

Annu. Conf., Columbus, OH, 2017.

[2] J. Metcalfe and A. P. Shimamura*, Metacognition: Knowing about Knowing.* Cambridge, MA: MIT Press, 1994.

[3] J. A. Turns, B. Sattler, K. Yasuhara, J. L. Borgford-Parnell, C. J. Atman, "Integrating reflection into engineering education," in *Am. Soc. Eng. Educ. Annu. Conf.,* Indianapolis, IN, 2014.

[4] National Academy of Engineering. "The engineer of 2020: Visions of engineering in the new century," National Academies Press, Washington D.C, 2004.

[5] H. A. Diefes-Dux and L. M. Cruz Castro, "2020 Reflection types and students' viewing of feedback in a first-year engineering course using standards-based grading," *J. Eng. Educ.,* vol. 111, pp. 283–307, April 2022.

[6] K. R. Csavina, C. R. Nethken, A. R. Carberry, "Assessing student understanding of reflection in engineering education," in *Am. Soc. Eng. Educ. Annu. Conf.,* New Orleans, LA, 2016.

[7] M. W. Steiner, J. Kanai, C. Hsu, R. Alben, "Analysis of reflective memos," in *Am. Soc. Eng. Educ. Annu. Conf.,* Vancouver, BC, 2011.

[8] D. H. Stratton, S. Anwar, M. Menekse, *"*How do engineering students' achievement goals relate to their reflection behaviors and learning outcomes?" in *Am. Soc. Eng. Educ. Annu. Conf*., Columbus, OH, 2017.

[9] R. Gerlick, D. Davis, S. Brown, M. Trevisan, "Reflective practices of engineering capstone design teams," in *Am. Soc. Eng. Educ. Annu. Conf.,* Louisville, KY, 2010.

[10] P. Lewis, D. Aldridge, P. M. Swamidass, "Assessing teaming skills acquisition on undergraduate project teams," *J. Eng. Educ*., vol. 87(2), pp.149–155, April 1998.

[11] P. L. Hirsch and A. F. McKenna, "Using reflection to promote teamwork understanding in engineering design education," *Int. J. Eng. Educ*., vol. 24(2), pp. 377–385, 2008.

[12] L. Aronson, "Twelve tips for teaching reflection at all levels of medical education," *Med. Teach.,* vol. 33(3), pp. 200–205, 2011.

[13] R. G. Bringle, and J. A. Hatcher, "Implementing service learning in higher education," *J. Higher Educ.,* vol. 67, pp. 221–239, 1996.

[14] L. E. Whitman and C. Mason, "Assessing service learning reflections," in *Am. Soc. Eng. Educ. Annu. Conf.,* Atlanta, GA, 2013.

[15] D. N. Bairaktarova and M. K. Pilotte, "Person or thing oriented: A comparative study of individual differences of first-year engineering students and practitioners," *J Eng. Educ*., vol. 109(2), pp. 230–242, April 2020.