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Using design timelines for tracking and reflection on design processes: Emerging insights

Prof. Reid Bailey, University of Virginia

Reid Bailey is a Professor in the Department of Systems and Information Engineering at the University of Virginia. He holds a BSE from Duke University and an MSME and PhD from Georgia Tech, all in mechanical engineering. His professional interests center on engineering design, education, and sustainability.

Dr. Jennifer A Turns, University of Washington

Dr. Jennifer Turns is a full professor in the Human Centered Design & Engineering Department in the College of Engineering at the University of Washington. Engineering education is her primary area of scholarship, and has been throughout her career. In her work, she currently focuses on the role of reflection in engineering student learning and the relationship of research and practice in engineering education. In recent years, she has been the co-director of the Consortium to Promote Reflection in Engineering Education (CPREE, funded by the Helmsley Charitable Trust), a member of the governing board for the International Research in Engineering Education Network, and an Associate Editor for the Journal of Engineering Education. Dr. Turns has published over 175 journal and conference papers on topics related to engineering education.

Krina Patel, University at Buffalo, The State University of New York

Krina Patel (she/her) is a doctorate student in Engineering Education at the University at Buffalo. She holds a M.S. in Mechanical Engineering from UC Berkeley and a B.S. in Engineering Science from Penn State.

Prof. Susannah Howe, Smith College

Susannah Howe, Ph.D. is the Design Clinic Director in the Picker Engineering Program at Smith College, where she coordinates and teaches the capstone engineering design course. Her current research focuses on innovations in engineering design education, p

Dr. Micah Lande, South Dakota School of Mines & Technology

Micah Lande, PhD is an Assistant Professor and E.R. Stensaas Chair for Engineering Education in the Leslie A. Rose Department of Mechanical Engineering at the South Dakota School of Mines & Technology. Dr. Lande directs the Holistic Engineering Lab and Observatory. He teaches human-centered engineering design, design thinking, and design innovation courses. Dr. Lande researches how technical and non-technical people learn and apply design thinking and making processes to their work. He is interested in the intersection of designerly epistemic identities and vocational pathways. Dr. Lande received his B.S. in Engineering (Product Design), M.A. in Education (Learning, Design and Technology) and Ph.D. in Mechanical Engineering (Design Education) from Stanford University.

Prof. Eli Patten, University of Washington

Dr. Patten received his B.S. in mechanical engineering at Washington State University and Ph.D. in mechanical engineering at UC Berkeley, where he studied the wear of ultra-high molecular weight polyethylene as used in joint replacements. At Berkeley, he was a graduate student instructor for several courses, covering various topics, styles, sizes, and class levels. After completing his PhD, he joined Makani Power, leading the design and development of the electromechanical tether for their new wind energy kite and was an inventor on over a dozen patents. In 2020, he joined the Mechanical Engineering department at the University of Washington as an Assistant Teaching Professor, where he leads the capstone design program and teaches the senior-level design sequence.

Dr. Cynthia J. Atman, University of Washington

Cynthia J. Atman is the founding director of the Center for Engineering Learning & Teaching (CELT), a professor in Human Centered Design & Engineering, and the inaugural holder of the Mitchell T. & Lella Blanche Bowie Endowed Chair at the University of Washington. Dr. Atman holds a Ph.D. in Engineering and Public Policy from Carnegie Mellon University. Her research focuses on design expertise, engineering design learning, considering context in engineering design, and the use of reflection to support learning.

Using design timelines for tracking and reflection on design processes: Emerging insights

Abstract

This paper focuses on better understanding the student experience of tracking and reflecting on design timelines during team-based engineering design projects. While it is clear that doing design is necessary to learn how to design, evidence has shown that the act of doing alone is not sufficient to promote design learning. Layering reflection on top of doing has shown promising results in learning generally - with a challenge for *design* learning being how to create authentic opportunities for students to reflect deeply and regularly on their design process. In this paper, we explore how the act of self-tracking activities to create visual representations of one's design process provides such authentic opportunities for students across different class years in group projects of different lengths. In particular, we examine the student experience of self-tracking their design activities by analyzing their responses to a survey completed at the conclusion of their projects. The majority of the data points to promising results, showing self-tracking helped students develop metacognitive awareness without viewing reflection as a detraction from their design work.

Introduction

This Education and Research Assessment paper focuses on better understanding the student experience of tracking and reflecting on design timelines during team-based engineering design projects. While prior work [1], [2], [3] has shown that *doing* design does not directly lead to *learning* design , reflection paired with doing has emerged as a way to promote design learning [4]. When students self-track their own design process to create "design timelines", the otherwise invisible process of design becomes visible. The act of creating the design timelines requires regular reflection by students, and the design timelines themselves provide a concrete process representation on which to reflect. Example design timelines, such as Figure 1 from a semester-long project, are shown throughout this paper. Each dot represents time spent in a certain design activity (the row) during a given time period (the column), which in Figure 1 is *weekly*. The dot size represents the amount of time spent on a specific design activity.

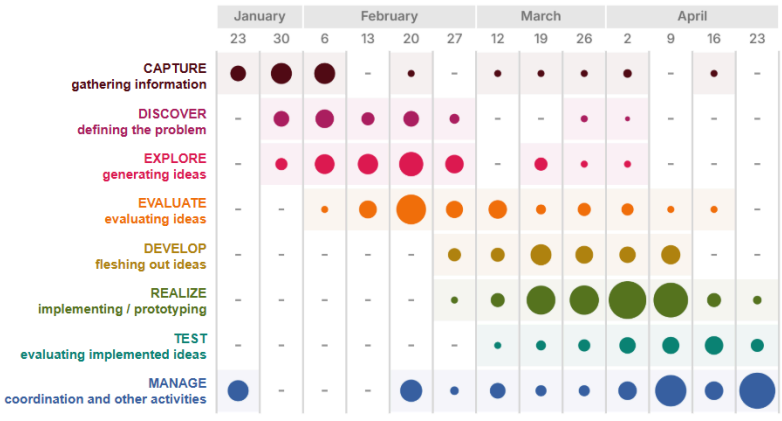


Figure 1. One-Semester Design Timeline Example

Two design educators had their students use design timelines for multiple courses over two years. Students shared their experiences related to used design timelines via a survey. Based on those survey results, in this paper we explore *the use of design timelines to track and reflect on team design processes to help students understand the design process and themselves as designers.*

Background and Prior Literature

This work is being conducted because of prior work in two areas: 1) work showing the disconnect between doing design and learning design and 2) work connecting the tracking of design activities (i.e., design timelines) with metacognition and reflection. This context provides an interesting opportunity to use the inherently reflective act of self-tracking one's design process to affect design intentionality.

Disconnect between Doing Design and Learning Design

In this paper, the learning of design refers to the learning of design *as a process*. The focus of such process learning is more about knowing when, for how long, and why to engage in different design activities than on being good at particular design activities or tools themselves (e.g., being able to write good requirements or being able to use a certain decision support tool).

Newstetter conducted a particularly insightful study on how students navigate learning design process versus learning how to do certain design activities and tools. In this ethnographic study, she was a participant observer on an engineering design team in a mechanical engineering design class [1]. In summarizing the study's findings, Newsletter writes that "Lesson one is that old ontologies die hard. As has been observed by others, doing design does not ensure the learning of design" [1, p. 126]. She continues that "even if the teacher sets up an environment that values and promotes knowledge building and learning to learn, students will not necessarily assume the concomitant roles of knowledge builders and learners" [1, p. 126]. She observed numerous instances where design tools and approaches that were provided by the instructor to *help* teams navigate the complexities of design were viewed by the team as assignments that *prevented* the team from completing their design work. For example, she observed her team filling out charts "to complete the assignment" while resisting creating anything that could be "useful as a group document" [1, p. 126]. Students, when told they needed to include a certain design activity or tool in an assignment, adopted a "a task orientation rather than a learning or communication orientation" [1, p. 127].

Further expanding on the disconnect between doing design and learning design. Dixon, in his 1991 critique of engineering design education, observes that "Mistake 4" of many engineering design courses is to "confuse experience with learning" [3, p. 67]. He writes that "not all experience is necessarily good. Moreover, experience is meaningless unless students learn something from it that is both useful and correct" [3, p. 67]. In work with a completely different methodology of assessing design learning (n=286), Bailey showed that students doing hands-on problem definition work in a first-year design class showed no change in their recognition that doing such work is an important part of design [2].

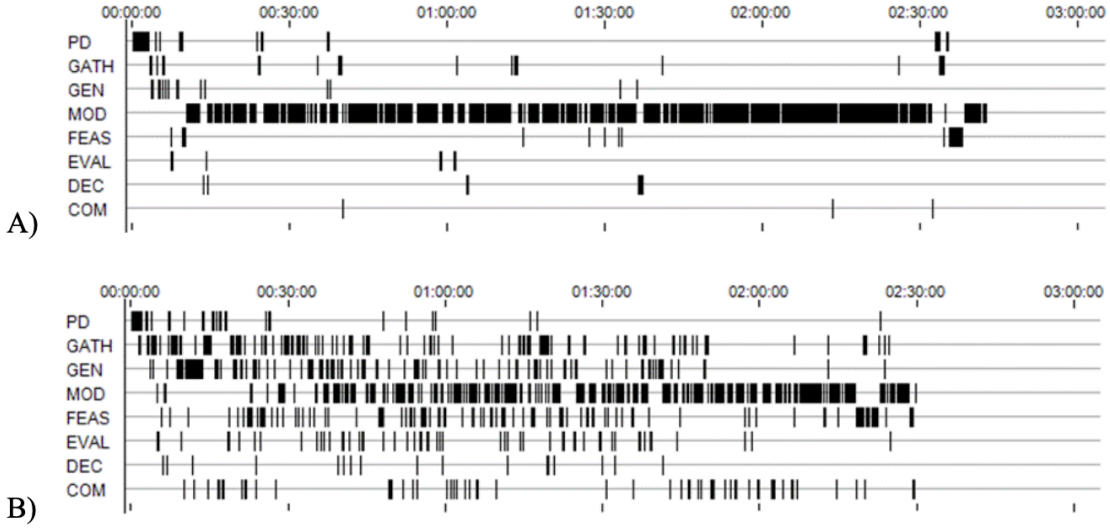
That said, creating reflection opportunities that authentically engage students with design can be challenging, as highlighted in the Newstetter study where she found that "even in a classroom

where a great deal of reflection and attention to learning is present, activities specifically developed to promote reflective practice, life-long learning and knowledge building are, for many students, nothing more than tasks to be completed" [1, p. 126]. While the teacher integrated reflective practice throughout the class in many activities and assignments, many [students] never grasped the importance of reflective practice, rejecting such teacher-orchestrated activities as "a waste of time" [1, p. 127].

Connection between Tracking Design Activities and Metacognition/Reflection

Many frameworks describe an engineering design process as comprising distinct types of design process activities, such as "problem definition" and "concept generation," that the designers progress through - often idealized as a linear order with some iteration but actually realized in a more complex pattern. The realized progression is generally invisible to the designer, but documenting the order of progression and duration at each activity and displaying these graphically as a timeline makes "...that design [progression] (or design timeline) visible, with time as an explicit element of the representation. These timelines, grounded in data, make the abstract concept of a design process more concrete, or visible" [5, p. 140].

Atman and colleagues have used this design timeline concept to study connections between design process and design outcome for engineering students and professionals via multiple studies. For example, Figure 2 shows two example timelines recorded by researchers from two different undergraduate engineering students completing a conceptual design of a playground for a fictitious neighborhood in a 3-hour exercise [6]. Time goes from left to right, with bars identifying what type of design activity the designer was doing at each point throughout the process. The legend at the bottom names the corresponding design process activities.



PD:	Problem Definition	FEAS:	Feasibility Analysis
GATH:	Gathering Information	EVAL:	Evaluation
GEN:	Generating Ideas	DEC:	Decision Making
MOD:	Modeling	COM:	Communication

Figure 2. Example Timelines from Two Different Participants in a Research Study Illustrate Very Different Design Processes for the Same Design Challenge

These timelines reveal patterns in how individuals approach design. While the two participants solved the same problem, they had very different processes. The timeline at the top of Figure 2 is from an incoming first-year student, whose playground design was of average quality, as measured by a rubric based on how well the design met the stated objectives. This student spent only a short time trying to better understand the problem (problem definition) and most of the time modeling the details of their design. The timeline on the bottom of Figure 2 is from a graduating senior who created a high-quality playground design. This student did more problem definition before modeling, gathered information throughout the process, communicated regularly, and iterated between design phases throughout the entire process.

The timeline representations resulting from the research have been used to teach engineering students about the design process with a presentation of research findings from first-year and graduating engineering students along with a series of activities to connect the timelines to themselves as designers [7], [8], [9]. Engineering students were excited to see design process representations based on empirical observation, as illustrated by a mechanical engineering undergraduate saying "Super valuable, Much more compelling to see real data, detail, makes me believe, instead of tuning out 'prescribed' info…Spend another day in our class talking about this research, please!" [8, p. 597].

Seventy-eight Civil and Human Centered Design & Engineering students who interacted with the timeline data for about one hour in a classroom setting were asked "Will information from this exercise affect how you will do design in the future? How?" [7]. An analysis of the open-ended student responses showed that students claimed that they would change their design behavior going forward. The student responses were grouped into three categories that map to the literature of metacognition [10], [11], with most responses in "Planning", followed by "Monitoring", and then "Evaluating." A sample of student responses include: "I will make sure to break up the time spent modeling to check other aspects of the problem. I will make sure to gather a lot of information/ideas in the beginning before I start modeling" and "I will make sure that I am not too focused on one type of activity" [7]. Such responses demonstrate that students intended to change their design behavior, in essence to self-regulate their design activities with goal-directed actions through metacognitive planning, monitoring, and evaluating [12], [13].

The design educators in this situation, however, were left to wonder if student engagement with one classroom activity would indeed change future behavior. This led to several seminars with a small number of students who did a deep-dive into the concept of *"design awareness"* [14]. Students engaged with the design expertise timelines along with actively engaging with design processes in multiple ways. Specifically, inspired by Chong and Foster's 2011 ASEE workshop, they made tracings of their design processes with paper and pencil "bubble sheets" [15]. The experience of making a physical tracing of their design process provided powerful insights for reflection for the students. This led the students to designing and implementing a web-based app called "Design Signatures" [16] that makes tracking and visualizing timelines more accessible. The app allows the user to input their own design model and create the timeline visualization automatically. Users can synchronously track a short design project and create timelines that resemble those from the original research displayed in Figure 2, or asynchronously track longer design projects and visualize them with discretized time segments and varying sized dots, such

as in Figure 3. The asynchronous timeline format still illustrates which design activities students engaged with during each time period: the larger the dot, the longer the relative time spent.

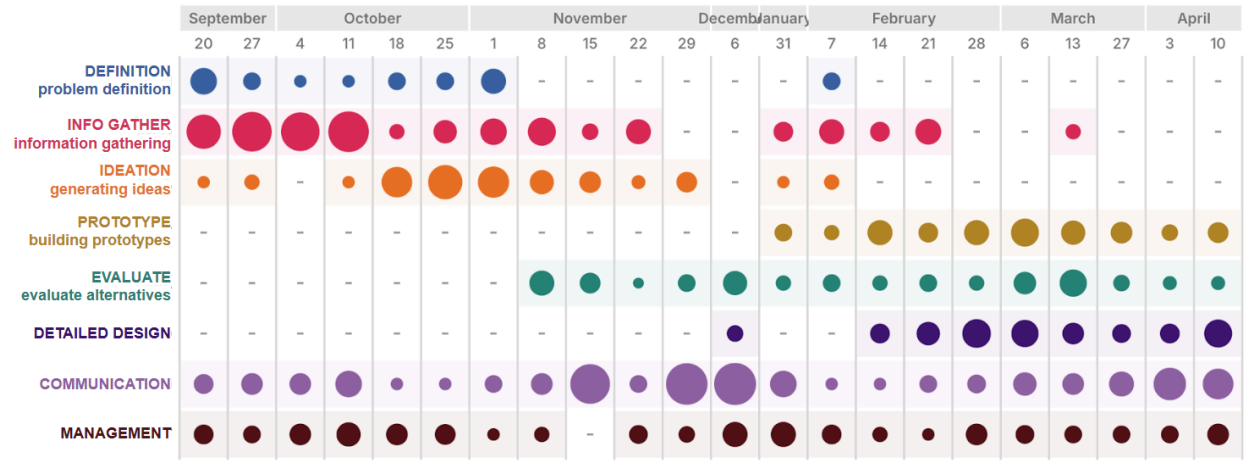


Figure 3. A Two-semester Design Timeline Collected Asynchronously by a Design Team

Asynchronous self-tracking has been integrated in several courses with longer-term design projects to support learning goals such as metacognition and self-regulation. While there are many different ways it can be implemented based on the specific context [17], key characteristics include the following:

- **Time is tracked at a regular interval by the students (the columns)** - for a meaningful interval is set by the instructor (e.g., every minute for a short activity, every day for a 2-week project, every week for longer projects)
- **Activities are binned into a set of design activities (the rows)** - the design activities are defined by the instructor and frequently match terminology used in class (e.g., note that the design activities in Figures 1 and 2 are not the same - demonstrating how any binning of design activities can be used)
- **Students regularly engage in reflection through recording their time** - as they map and add up the amount of time spent in each design activity for each time interval, they necessarily think about their design process
- **Students also engage in reflection on the overall process at key points** - the visual design timeline representation are used at key points in a project to reflect on the overall design process

Transitioning to This Study

The remainder of this paper features work by two educators whose students used the app to asynchronously track their own design processes. The student reactions offer insights into how their tracking of design timelines via the app supports metacognition and self-regulation as it relates to design and more generally the ways in which such use can address the learning/reflection gaps identified by Newstetter and others.

In this paper, we explore student experiences from the first implementation of Design Timelines. Our overarching question is: *Does the use of design timelines to track and reflect on team design*

processes help students understand the design process and themselves as designers? Specifically, we investigate:

- RQ1. Do design timelines afford students the opportunity to reflect on design processes?
- RQ2. Does the use of design timelines support self-regulation of design processes during project engagement?
- RQ3. Does the use of design timelines support preparation for future self-regulation, such as through insights about design processes and articulations of intentions?

Methodology

In this paper we studied students asynchronously self-tracking their design timelines over the course of weeks or semesters. We used survey data from these students to address the research questions.

Sites

Students in the study were seniors in a 2-semester capstone, juniors in a 1-semester independent studies project, and first years completing a 3-week project, a 5-week project, and a 1-semester project. The juniors and seniors were two different groups of students at a small private college and the first-years were enrolled in a 2-semester course at a medium-sized public university. Table 1 provides details on the numbers of students by class year and project duration.

Table 1. Participating Students (90 Total) across Classes, Years, and Project Duration

	First-Year Students	**Third-Year Students**	**Fourth-Year Students**
3 week project	**47 total** 30 - fall 2023 17 - fall 2024	-	-
5 week project		-	-
1 semester project	**36 total** 4 - spring 2023 32 - spring 2024 (Most of the Sp24 students did the 3- and 5-week projects in F23)	-	-
1 semester independent study	-	**3** - spring 2023 (all on the same team project)	
2 semester capstone	-		**4** - fall 2023 and spring 2024 (each on a different team project)

At regular time intervals in the design projects, students reflected on their design activities and estimated the amount of time they spent in each activity of the design process model provided in

their respective class. Beyond the reflective practice of creating the timelines, the students also reflected on the resulting design timelines themselves at different points throughout the projects.

One way that students are engaged in reflection at the midpoint and endpoint of projects is through comparing design timelines from an entire class. For example, Figure 4 shows seven design timelines from seven different teams from the Fall 2023 sample on a five-week design project.

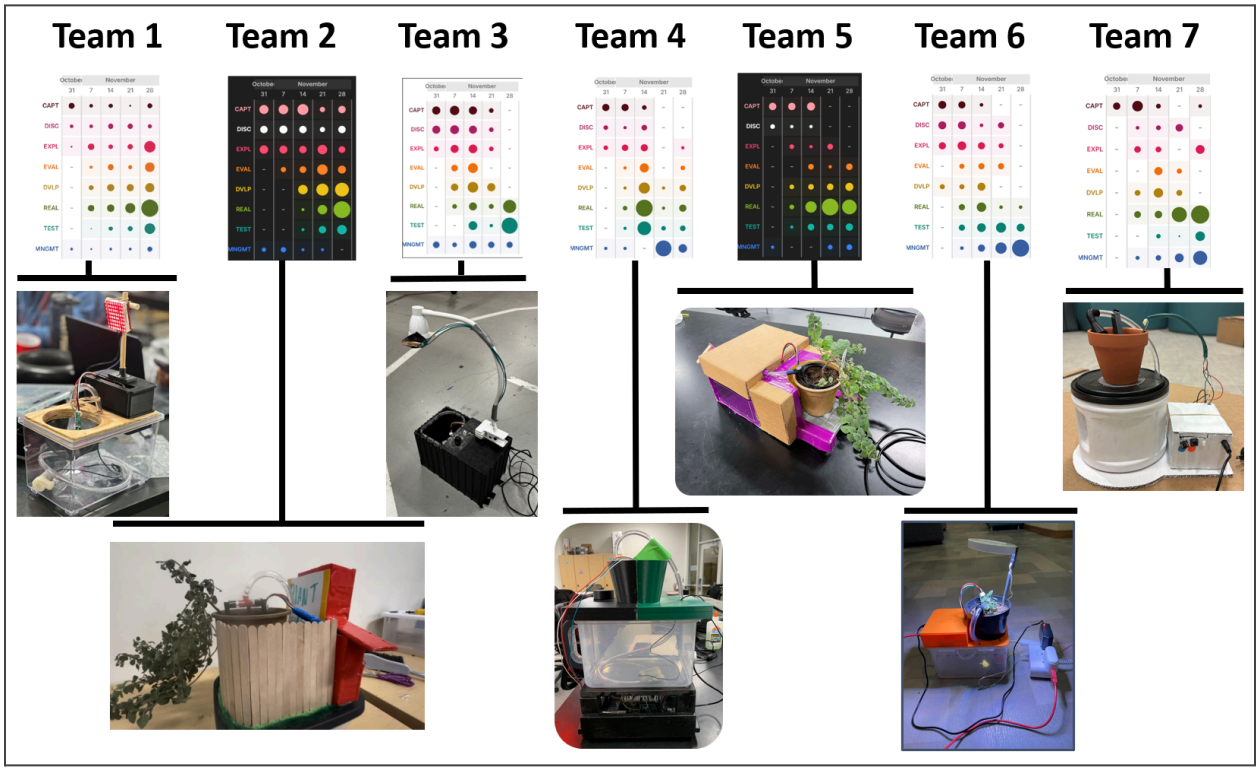


Figure 4. Design Timelines from Seven Teams in the Same Class Are Used for Reflection

Even though design educators frequently embrace the notion that there is not one "right" design process, students rarely engage in considering the design process of other teams in a typical design class; they only experience their team's design process. Observing and reflecting on design timelines from multiple teams builds on Kathryn Shroyer's work to employ variation theory in design teaching [18], [19], where the collective experience across all of the projects can broaden the individual experiences within a single project. Table 2 provides details about the design timeline creation and associated reflection for each project.

Table 2. Key Aspects of Design Timeline Creation

	Design Activities (the rows of a design timeline)	**Time Interval for Data Collection (the columns)**	**Reflection Approach and Timing**
3 week project	Capture (Info Gather) Discover (Prob Defn) Explore (Ideate) Evaluate Develop Realize (Any Building) Test Manage/Other	Semi-weekly	Written reflection at end of project
5 week project		Weekly	Written reflection at end of project
1 semester project		Weekly	Written reflection at midpoint and at end of project
1 semester independent study	Problem Definition Info Gather Ideation Prototype Evaluate Detailed Design Communication Management	Weekly	Informal discussion during weekly group meeting
2 semester capstone		Weekly	Informal discussion three times during the year

Data Collection

At the end of the term or project, all students also completed an individual Design Timelines Survey, where they reported on their identity as a designer and the intentionality with which they think about the process of design while designing. These end-of-project design timelines surveys included a set of open-ended response questions (see Table 3) followed by a series of Likert-scale prompts (see Table 4). Ninety students at two different institutions completed the survey across two years (see Table 1).

Table 3. Open Response Questions on Design Timelines Survey

Survey Prompt*
Q1. What are your biggest takeaways from tracking your design timelines?
Q2. Did tracking your design timelines affect how you engaged in design in your project? How?
Q3. Has tracking your design timelines affected how you plan to do design in the future? How?
Q4. How do you think the [Research Team] could better use the timelines to encourage intentionality with design?

* Note: Wording differed slightly for the different classes to tailor the question to the specific class/project experience.

Table 4. Likert-Scale Questions on Design Timelines Survey

<table>
<tr><td colspan="3">Survey Prompts and Options
For each of the statements below, indicate if your agreement with this statement has
“gone up”, “gone down”, “stayed about the same” or “do not know”
after tracking your design timelines in this project.</td></tr>
<tr><td colspan="2">S1. I am a designer</td><td rowspan="5">[ ] gone up
[ ] gone down
[ ] stayed about the same
[ ] don't know</td></tr>
<tr><td colspan="2">S2. I do design</td></tr>
<tr><td colspan="2">S3. I can describe my own design process</td></tr>
<tr><td colspan="2">S4. I can identify a good design process</td></tr>
<tr><td colspan="2">S5. I have a specific design process I aspire to</td></tr>
<tr><td rowspan="6">When I engage in design experiences, I feel like…</td><td>… I am aware of where I am in my design process [S6]</td><td rowspan="6">[ ] gone up
[ ] gone down
[ ] stayed about the same
[ ] don't know</td></tr>
<tr><td>… I plan my design process before I start [S7]</td></tr>
<tr><td>… I monitor my design process while I am in it [S8]</td></tr>
<tr><td>… I evaluate where I am in a design process [S9]</td></tr>
<tr><td>… I make conscious decisions about my design process [S10]</td></tr>
<tr><td>… I reflect on my design process after I finish a design project [S11]</td></tr>
</table>

Data Analysis

The student responses from the survey are the focus of this paper as they help to answer the research questions noted previously. Analysis of the open-ended responses (Q1-Q3) followed standard thematic analysis techniques. We engaged in data familiarization via manual open coding and exploratory coding with generative AI tools. Ultimately, the data were coded in alignment with each research question. As will be presented, an additional emergent area of interest emerged during the coding and is presented in a non-traditional format. For the quantitative results, Likert-scale questions from Table 4 were tabulated and the percentage of each response was calculated.

Results

RQ1. Do design timelines afford the student the opportunity to reflect on their design processes?

Most students (over 90%) had concrete, specific, and generally positive things to say about the impact of the experience. These substantive responses are explored in the following discussions of RQ2 and RQ3.

The limited number of negative responses reinforce the overall substantiveness of the student response to the tracking activity. We identified at least 15 of the 218 responses (less than 10% of the data) as containing a "no impact" sentiment. For example, in response to the question about how the tracking of design process affected engagement in the design project (Q2), such "no impact" responses included "Not really, it was just a way to track and a cool visualization" and "It was more so another thing to complete rather than a core part of our project." In response to the question about how tracking of their design timelines had affected their plan to do design in the future (Q3), such "no impact" responses included "I don't think I would ever track this in the real world unless it was for a class and I thought that the teacher would like it." And in response to the query about takeaways, one response was simply "N/A." While the majority of the responses do provide a “yes” answer for this research question, the existence of these "no impact" responses are valuable because they contain the kinds of responses that educators might expect/worry about seeing and thus the “no impact” responses put into perspective the positive orientation of the remainder of the data.

RQ2. Does the use of design timelines support self-regulation of design processes during project engagement?

Student responses indicate that the design timelines tracking significantly influenced students’ ability to think about their own design process. This theme encompasses metacognitive and reflection skills at both the individual and group levels. Students' responses included setting goals based on prior knowledge and preparing for design activities before engaging in them. This metacognitive dimension involved strategizing about time allocation and foreshadowing potential challenges. As one student explained, "I was more aware of how we allocated our resources (people and time) on different areas of the project (prototyping / building vs problem definition work)" (Q2). This recognition allowed them to make more informed decisions about allocating time and resources, with another student noting, “I think having capture/explore as two categories where we would need to track hours encouraged me to spend more time developing a strong problem definition/assess the context of the problem more in depth than I otherwise would have” (Q2).

The design timeline tracking itself also helped the students recognize when adjustments were needed in the design process. It also made their thinking more accessible for reflection. With one student sharing, "I tend to get stuck in one step of the process, rather than moving around spending equal time on each step" (Q1). This self-regulation helped students make progress and avoid design fixation or convergence. Another student noted, “it encouraged us to actively think about HOW we were designing as opposed to 'just doing it'" (Q2).

Beyond the primary design-related themes, students also identified various other benefits of timeline tracking. Time management emerged as a significant benefit, with one student sharing, "It also made us more aware of our time management for certain categories and maximize our efficiency" (Q2). This sentiment was not only for individual time management but also for their teams, which improved team coordination and communication. As one student shared, “My biggest takeaway is that the design timelines allow groups to thoroughly reflect on their projects and how they divided their time. I think having these timelines helped improve our time management from the PDP to HCD projects, for instance by prototyping earlier" (Q2). Notably, some students mentioned increased motivation, as one student put it, the tracking “was a

motivation for me and pushed me to spend more time on this project" (Q2), while another found, "using the design timeline put pressure on me to contribute to the project in a meaningful, categorical way" (Q2). This motivational and management aspect suggests that the design timeline activities may have benefits beyond just reflective and learning purposes, potentially serving as accountability and teaming tools that encourage more consistent engagement with design work. It should be noted that individual time spent on the project was not reported back to the instructor - indicating that motivational aspects were more about accountability to teammates rather than to an instructor.

RQ3. Does the use of design timelines support preparation for future self-regulation, such as through insights about design processes and articulations of intentions?

Several responses show evidence of students' evolving understanding of what design is as both a concept and process. This theme represents a fundamental shift in students' perception of design, from viewing it as a purely creative or aesthetic activity to recognizing it as a structured yet flexible process with distinct phases and iterative characteristics. This shift was evident when students realized, as one noted in (Q3), "Yes, it taught me that a "good design" did not come from jumping right into building (realize) stage. I will leave enough time for both figuring out the real problems & needs and evaluating and optimizing the design in future planning." The visualization and tracking of their process allowed students to recognize the design's iterative nature, with one student noting how "...as we realized that oftentimes better engineers go back and forth between activities throughout their entire process. It also made us more aware of our time management for certain categories and maximize our efficiency." in response to (Q2.)

For many, this led to also recognizing the importance of front-end design work. When asked directly about future plans, students were able to be specific. Students expressed specific changes they planned to implement, stating, "Yes, I know I need to spend more time focusing on capturing, discovery, and exploration rather than jumping straight to prototyping" and "Yes, tracking the time spent for various categories has made me more aware of the significance of continuous iterations during a project" (Q3).

Particularly significant was the strong connection to continue with the design timeline as a visualization tool. One student emphasized "After seeing the hard work laid out in such a visual way that actually provides me with some sense of pride in my work. After using the design timeline, it has provided a good structure to the process and can guide you through each step, allowing reflection of the other "processes" (Q3). Another student has similar sentiments but expanded the use, noting, "I believe that creating a design timeline acts like creating a plan of action. By being able to plan a long design or assignment and being able to record the progress, it makes it easier to complete big and complex assignments. I believe that I will be using something similar for my daily life too" (Q3). This demonstrated how students recognized the transferability of design timelines as a planning and visualization tool beyond academic projects into personal practices.

After the open-ended questions, students were asked how much they agreed with each of the Likert-scale statements (see Table 4). As shown in Figure 5, the majority of student responses indicated improvement across all measured statements of self-regulation and metacognition, particularly in relation to the design progress (S6-S11), self-identification of their design identity,

and capabilities (S1-5). Notably, 77% of students reported that their ability to "make conscious decisions about [their] design process" has "gone up" after using design timelines. While 88% indicated that their capability to be "aware of where [they are] in [their] design process" has also "gone up." Additionally, 67% of students reported having "a specific design process I aspire to" had "gone up", showing intention formation for future practice.

These quantitative results demonstrate that the design timeline not only supported immediate reflection but also fostered preparation for future self-regulation through enhanced metacognitive awareness and planning-monitoring-and evaluating design approaches.

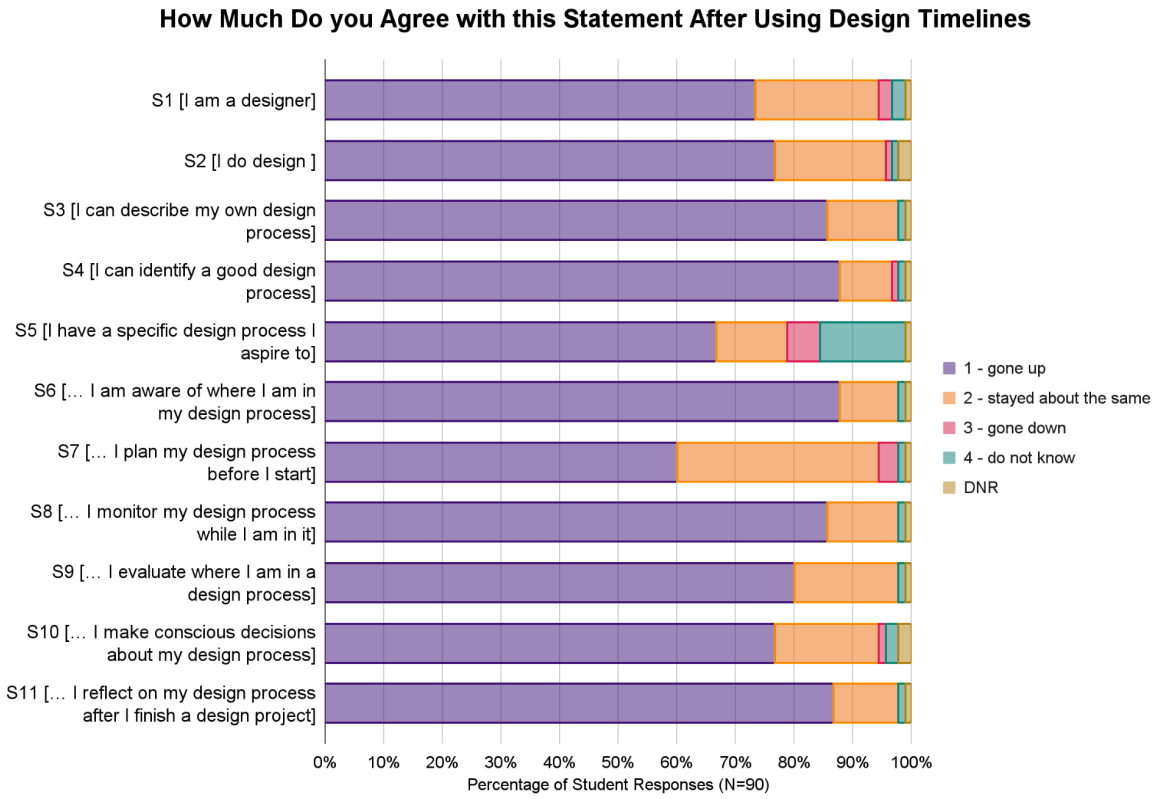


Figure 5. Results from Design Timelines Survey (n=90)

Bonus: The Tracking Effort

An expected feature of the data was the range of ways that students framed how the tracking experience affected them. To surface this, we identified the ways that the students described their relationship to the tracking effort. We have chosen to represent this set of findings in the form of a poem to keep them separate from the previous analysis. The poem was created by generative AI (Claude 3.7 Sonnet) to synthesize excerpts from student responses reflecting this finding.

Encouraged me, forced me,
made me more conscious, more cognizant.
Had to be aware so we could categorize it later.
I was stressed out, but...

Keeping track pushes me to do more work, made me try, made us prototype fast.
Provides me with some sense of pride.
It can guide you through each step, helpful to look at previous timelines, interesting.
It was a motivator, kept us present, reminded us.
Knowing I had to track later made me more aware.
Made it seem more acceptable, made me more aware, made us...
motivation for me, pushed me to spend more time.
Put pressure on me to contribute in a meaningful, categorical way.
A relaxation period, a useful tool to record.

Discussion

The results of this study provide promising evidence that design process tracking/timelines can be an effective approach for supporting design learning--both immediately as a metacognitive scaffold and broadly as a way to gain knowledge for the future. The qualitative responses to (RQ1) demonstrated that design timelines did indeed afford students opportunities for reflection on their design processes with over 90% of responses indicating some form of benefit from the reflective work of tracking design process, reviewing timelines, and having conversations about the timelines. In terms of supporting self-regulation during project engagement (RQ2), students reported increased awareness of their design process in real-time, which appears to have facilitated better time management and team coordination. Looking toward future design work (RQ3), students articulated insights they had gained about design process efforts, articulated specific intentions to modify their approach to design based on insights gained through timeline tracking, and indicated a desire to continue using design timelines as a visualization tool beyond the requirements of the course. These findings are reinforced by our quantitative results, which show that 74-88% of students reported increased design awareness, design intentionality, and self-identification as designers after using design timelines.

Alongside the responses to RQ1-RQ3 is the data showing students as having a nuanced and sometimes contradictory relationship with the tracking/timeline effort. Students characterized the tracking experience using language that ranged from obligation ("forced me," "had to be aware") to motivation ("a motivator," "pushed me") to reflection ("a relaxing period," "useful to record"). This spectrum of responses demonstrates the complex ways students internalized and experienced the tracking requirement. What is particularly interesting is how these seemingly contradictory experiences—feeling both "stressed out" and experiencing "a sense of pride"—could coexist within the same pedagogical intervention. Even when students perceived the tracking as something that "put pressure" on them, they often framed this pressure as productive, leading to more meaningful contributions and increased engagement with the design work. This range of experiences suggests that the value of design timeline tracking may not be tied to whether students find it enjoyable, but rather to how it shapes their engagement with design regardless of their emotional relationship to the tracking itself. The fact that even students who described being "pushed" still reported benefits in terms of awareness and intentionality implies that the pedagogical value of tracking may transcend students' subjective experience of the activity.

These findings, taken together, suggest a potential system viewpoint for understanding how this broad reflective engagement stands in contrast to Newstetter's [1] observation that students often

view reflective activities as "tasks to be completed" or "a waste of time." We propose that design timelines succeeded where other reflective activities have failed because they created what we might call an enabling cycle of reflection that integrated productively into the design effort itself. Unlike reflection activities that require students to step away from their design work, design timeline tracking seemed to bring the students closer to their design experience.

This integration appears to have three key components. First, the tracking activity promoted in-the-moment awareness without being experienced as negatively disrupting workflow. The visual nature of the timeline representations may have contributed to this acceptable awareness. By making the abstract concept of "design process" tangible and visible, timelines created a concrete artifact for reflection.

Second, students experienced benefits: tangible improvements in time management, team dynamics, and motivation. These immediate returns on investment made the reflection activity feel worthwhile rather than burdensome. It was not a task solely being done for the instructor or for a grade - it was a task that led to direct benefits. This realization of direct benefits to their project is in contrast to the experiences observed by Newstetter, where the grading system pushed students who started the term with a "learning view" to take on a "task view" after a disappointing evaluation of their first assignment incentivized the team to focus solely on "achieving 10s" on the rubric [1, p. 127].

The experience of tracking their design process while they are engaged in a project enabled students to explicitly enact what they were learning about as they were learning it - not making a note to themselves to do something in the future. The Scalone et al. paper described students' statements about themselves as future designers after engaging with a one-hour classroom activity where they interacted with timelines in a lecture-based activity. One student claimed that as a future designer "I will make sure that I am not too focused on one type of activity" [7]. In the current work, students reported being actively engaged in the tracking of their own design processes. In other words, student learning is in the present tense, in addition to future tense.

Third, the combination of real-time awareness and immediate benefits created a foundation for future-oriented learning. Students could articulate specific changes they intended to make in future design work and expressed enthusiasm for continuing the practice.

This three-part cycle explains how design timelines transformed what might have been experienced as merely another assignment—as captured in the poetic representation phrases like "forced me" and "had to be aware"—into something that students ultimately found valuable, as reflected in expressions like "a sense of pride" and "a relaxing period." The initial external pressure or obligation evolved, for most students, into meaningful engagement precisely because the tracking activity offered immediate benefits while supporting longer-term learning goals.

This stands in contrast to reflection activities that students experience as separate from or even interfering with their design work. When reflection is positioned as something that happens after or outside of design activity, it can feel disconnected from the hands-on experience that students often value most. Design timelines, by contrast, make reflection an integral part of the design

experience itself, thereby addressing the disconnect between doing design and learning design that has been identified in previous research.

It is important to remember that not all students found the design timelines valuable, with approximately 10% of responses indicating little or no impact. This reminds us that no single pedagogical approach works universally, and future research might explore which student characteristics or learning preferences predict positive responses to design timeline activities.

Conclusion

While prior work has shown that doing design does not directly lead to learning design and reflective activities are often viewed by students as tasks to be completed or a waste of time, our research offers preliminary evidence that design timelines create an effective bridge between doing and learning. Put metaphorically, in the journey of design education, reflection is often perceived as a mandatory pause, a barrier interrupting students' forward momentum on their design project "train." Design timelines show potential to transform this perception by functioning as the tracks themselves—simultaneously guiding progress while supporting reflection. Like railway tracks that both direct and enable a train's movement, design timelines seem to provide structure while allowing students to visualize their journey in real time. The tracks helped determine where the train has been, where it is going, and how it can arrive at its destination more effectively.

Put theoretically, the majority of our data shows that design timelines helped students develop metacognitive awareness without viewing reflection as a detraction from their design work. This integration addresses the fundamental disconnect between doing design and learning design identified in previous research. Our next steps focus on broadening the institutions and types of classes in which design timelines are used, with the goal of refining how this approach can guide students' design journeys while supporting their reflective practice across diverse educational settings.

Many different timeline creation methods satisfy the objective of providing students with an external boundary object that can be a focal point for data collection and reflection about their design processes. While the authors have found the app [16] used in the research in this paper to be convenient and the representations compelling, it is not the only method to track design processes. Other methods we have used include filling in a set of bubbles on paper, using a Google form, or inputting time estimates directly into a spreadsheet [20], [21].

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