Work in Progress: Using Design Signatures to highlight differences among various senior Capstone design project sponsor and deliverable types

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Abstract

Design Signatures began with the concept that as engineers design, they navigate a design process that differs based on the goals of the project, the experience of the designer, and various needs of stakeholders. Quantities of time spent and tracked across pre-defined design steps and activities comprises the *Design Signature,* unique to each project. Combining the concepts and tools of Design Signatures with self-reported time tracking data in a Capstone Senior Design course not only helps students develop professional skills and understand how they're spending time on projects but also provides the instructor team with tools to promote student accountability and track project health, as well as providing valuable data to compare projects and understand predictors of project success.

For academic year, 2024-2025, instructors of Agricultural and Mechanical Engineering Capstone Design at the College of Engineering at the University of XXXX ("XXX") asked students to track their project work time across ten design process activities including 1) gathering information, 2) identifying needs, 3) problem definition, 4) generating ideas/ideation, 5) modeling, 6) evaluation, 7) feasibility analysis, 8) decision making, 9) implementation, and 10) communicating results. The breakdown of time logged by activity varied across project sponsor-type (industry-sponsored, competition, non-profit sponsored, internal sponsor, and entrepreneurial/non-sponsored) and across final deliverable(s) expected (CAD drawings, model-based design/simulation, physical prototype/product, bill of materials, or process design). The goals of the work-in-progress study were to highlight similarities and differences across project sponsor and deliverable types and to see how time logged correlates with project success as evaluated by course instructors, field experts, and project sponsors.. In this work in progress, we show differences in time logged relative to sponsor category and deliverable type. In addition, we provide examples in which the design signatures method allowed the instructors to intervene when too little time was logged at various points in the design process.

1. Background

Developed by the Center for Engineering Learning and Teaching in the Human Centered Design and Engineering Department at the University of Washington (UW), "Design Signatures" are visualizations of a design process. An example of a design signatures plot from UW is shown in Fig. 1. This figure shows time spent by week in eight design process categories across an 8-month project. The eight categories from top to bottom chart a standard design process progression, i.e., a designer begins by defining a project, then progresses through information gathering, ideation, prototyping, evaluating, and communicating. The area of the "bubbles" corresponds to the quantity of time spent in any week on a particular design process activity.

As the example project progresses, activities shift away from project definition and information gathering toward ideation and prototyping and finally to the development of a final, detailed design and to the communication of results.

In general, how a design practitioner, educator, or researcher might use information from a design signature varies, but at its core, a design signature is a unique snapshot of a design project

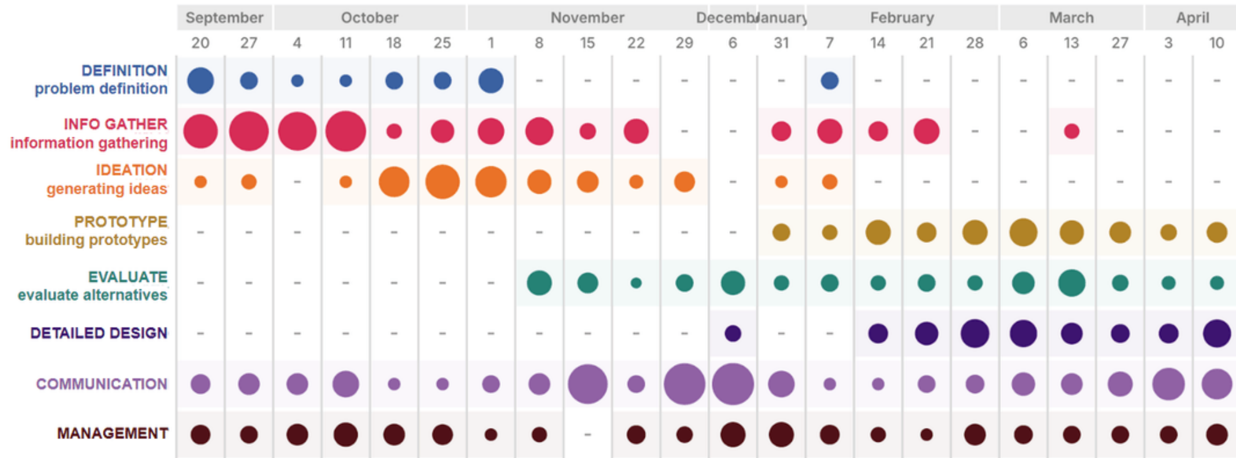

Figure 1. A design signature for an 8-month project. From https://www.designsignatures.org/design-signatures/example-design-processes.

that provides valuable information about the nature of a design project. In the context of undergraduate engineering education, a reasonable goal of using design signatures is to improve student outcomes and better prepare engineering students for their eventual careers in engineering.

Previous studies have used design signatures to characterize how engineering students engage in the design process compared to experts [1], how freshman engineering students engage in design compared to senior engineering students [2, 3], and how design signatures can be used as an educational tool [4, 5]. Other studies have looked into idea generation can be incorporated in design projects well outside the initial idea generation phase [6] and that effective idea generation has the greatest impact on positive results [7]. Design signatures, unique to every project [8], can be used to chart and quantify the time spent in ideation.

In the current study, we show how the balance of time spent in any design activity varies given the nature of the project sponsor (e.g., corporate/industrial, UGA-internal researcher, Club/competition, non-profit, etc.), the type of prototype or product created (physical, simulated/digital, process), and whether a team struggled during Capstone Design due to conflict, project complexity or ambiguity, and other factor.

2. Methods

In this section, we introduce the participants (Capstone Design students and project sponsors), the data source (time logging data), the prototype and time logging categories, and the methods of data analysis.

Data were gathered from students' self-reported time logging in the 2024-2025 academic year (AY24-25). These data were considered alongside other evaluation data and other observations of team performance and in-team conflict metrics to better understand how project sponsor type (industry, faculty/research, non-profit, competition) and deliverable type (physical prototype, digital/simulated model, process, BOM) affected the design signature.

2.1. Participants

Capstone Design students in agricultural engineering (AENG) and mechanical engineering (MCHE) at XXX have been required to log project work hours in EduSourced, XXX's project management platform, since 2020. Data for the current study was derived from participants in Capstone Design in AY24-25. This included 6 AENG students and 198 MCHE students working on 44 projects. Students are assigned to projects based on several factors including preference (students rate and rank their top 10 choices), students' leadership style [9], faculty-determined project priority, and required student expertise for a given project. Students are normally assigned to one of their top-3 choices.

The Capstone program at XXX hosts projects sponsored by various clients. Those under study here included:

- 20 local and regional industry projects ("IND")
- 5 faculty projects internal to XXX ("INT")
- 5 non-profit organization projects ("NP")
- 10 student clubs and association projects (normally competition projects, "COMP")
- 4 non-sponsored entrepreneurial projects ("ENT")

2.2. Prototypes

Teams for Capstone Design generally create, develop, test, and refine prototypes (deliverables) of one or more types depending on the needs of sponsors and other stakeholders. Most commonly, the primary deliverable included a physical prototype (PP, 15 projects), a process design (PD, 7 projects), a 3D model (CAD, 3 projects), a model-based design (i.e., simulations, MBD, 5 projects), or a bill of materials (BOM, 1 project). Many projects were required to produce a combination of these deliverables. Here, we focused on the primary deliverable.

2.3. Time Logging Categories

Individuals were asked to log time between the start of fall semester, 2024, and the end of spring semester, 2025, in the following time logging categories:

- Problem Definition (PD)
- Identify needs (ID), e.g., stakeholder meetings, interviews
- Gather Information (GATH), e.g., self-guided learning/research
- Generating Ideas/Ideation (GEN)
- Modeling (MOD), e.g., calculation, simulation, coding, prototyping
- Decision-making (DEC)
- Evaluation (EVAL), e.g., design of experiments and other testing
- Feasibility Analysis (FEAS), e.g., financial analysis, verification
- Implementation (IMPL), e.g., validation
- Communicating results (COM), e.g., writing, presenting

2.4. Time Logging Data Analysis

Time logging data was analyzed in several ways. Firstly, we summed hours within each time logging category for each project sponsor type and created graphs to see differences. We hypothesized that teams working on different project types spent time in differently. For example, we might ask, did entrepreneurial projects log more hours than industry projects? Or,

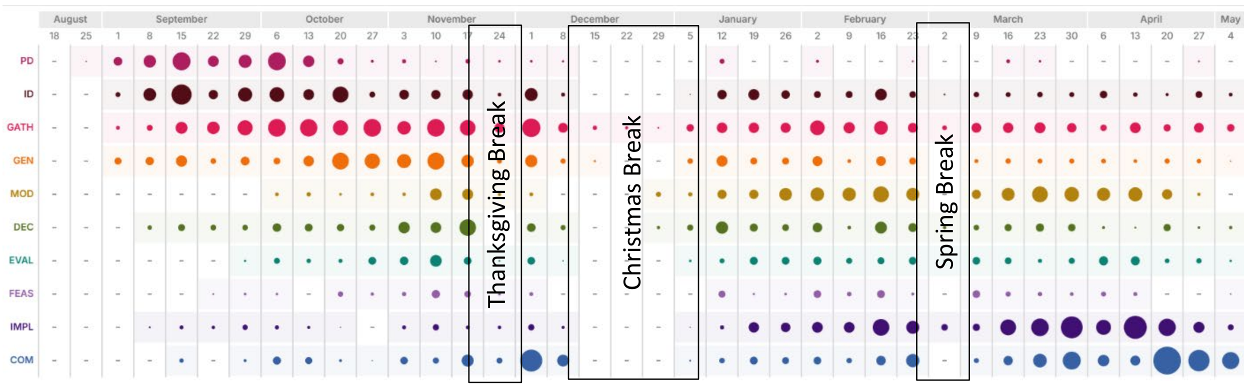

Figure 2. Design Signature for AENG and MCHE Capstone Design project during AY 24-25.

did internal projects spend more time understanding client needs that competition projects? To confirm differences, the data were displayed on graphs along with the 95% confidence interval (CI) for the mean of that particular metric. Any two categories for which the CI did not overlap could be considered as significantly different at a confidence level, $\alpha = 0.05$.

Secondly, to show if time logged differed by deliverable type, we followed the same method. We hypothesized here that teams spent time differently depending on the type of prototype produced. To analyze this data, we observed time logged for teams considering the primary deliverable required and produced by the team although secondary and tertiary deliverables may have also been required.

Finally, we identified five projects that struggled during the 8-month time frame due to conflict or other issues based on our observations of grades, peer reviews, and other communications and compared those projects' design signature data to the average project, i.e., average hours logged and CI by category for all projects.

We recognized that self-reporting of hours worked could be manipulated to show greater effort than was actually accomplished. As a means to validate self-reported hours, i.e., to avoid or identify misreporting, we asked students to connect time logged to activities reflected in their design notebooks. For each notebook entry, students were asked to indicate how much time was spent on that particular entry. With this reporting, instructors could check that hours logged matched a specific activity. While we have not yet evaluated the specific matching of hours to activities in the design notebooks, we did track pages produced by students in their notebooks over the two-semester course discussed in this work. Course TAs recorded page counts every two week and reported this data. Only quality pages were counted. To validate this method, we compared page counts to hours logged to confirm equivalence (pages per hour) across project sponsor types and deliverable types.

3. Results and Discussion

Figure 2 shows the design signature for all teams across the ten design process categories for our 8-month Capstone Design process. This figure represents the design signature for the AENG-MCHE Capstone Design *program* for the year in question. Teams logged a total of 12,219 hours with individuals logging on average 61 hours each.

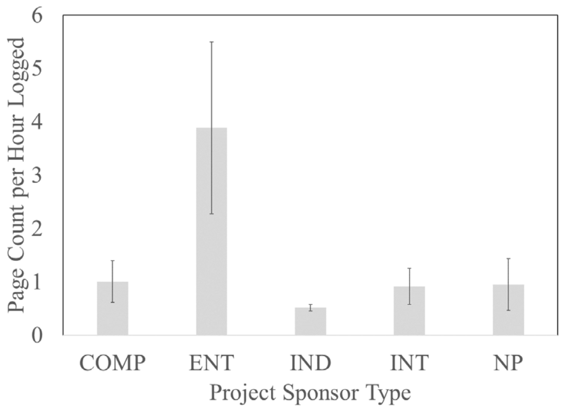

Figure 3. Average page count per time logged for sponsor type: Competition (COMP, 0.77 pg/h), Entrepreneurial (ENT, 2.3 pg/h), Industry (IND, 0.55 pg/h), Internal (INT, 0.69 pg/h), and Non-profit (NP, 0.54 pg/h).

Considering a normal progression of design activities, i.e., moving from PD to IMPL and COM, we observed that the balance of time shifted from earlier design phase activities, e.g., PD, ID, GATH, and GEN, to later design phase activities, e.g., MOD, DEC, EVAL, FEAS, IMPL, as the semester progressed. Holiday breaks are noted in Fig. 2 during which students were not expected to continue working.

Before comparing hours logged as a function of project sponsor category and deliverable type, we attempted to validate that teams with different sponsor types were not inflating self-reported hours. To validate whether teams inflated hours, a comparison was made of design notebook page counts generated by students per hour. Only quality notebook pages as defined by a grading rubric were counted. The rubric was shared with students and the TAs that counted pages. Individuals, on average, generated 45.1 quality pages through AY24-25.

3.1. Effect of sponsor type on hours logged

Figure 3 shows notebook pages generated per hour by students working on COMP, ENT, IND, INT, and NP sponsored project. This figure clearly shows a large disparity between ENT projects and all the other types. We propose that this is due to the emphasis placed on time logging among different course sections of students. All ENT project students were in one section, and the average time logged by students on ENT projects was 23.4 h compared to an average of 73.7 h per student on projects sponsored by other sponsor types (COMP, IND, INT, and NP). If we make the assumption that the disparity was indeed due to unlogged time and that ENT teams actually spent similar time, i.e., 73.7 h, the page count per hour reduces to 0.73 pg/h, similar to the other categories.

Since the academic year for which data are shown here, we have combined the ENT-centric section of Capstone into the main section of AENG-MCHE Capstone such that expectations and delivery of content are more analogous across project sponsor types.

Next, we looked at data to determine if teams logged time differently for different sponsor types. For example, did entrepreneurial projects log more hours than industry projects, which of course, we have already noted that they did.

Figure 4 shows differences in time logged across project sponsor type. Error bars represent the 95% confidence interval. In comparing time logged between two different categories, if error bars do no overlap, time logged in those two categories is statistically different at α=0.05. The data from Fig. 5 indicated industry- (IND) and non-profit- (NP) sponsored projects, spent significantly more time working on their design process than any other group, although not

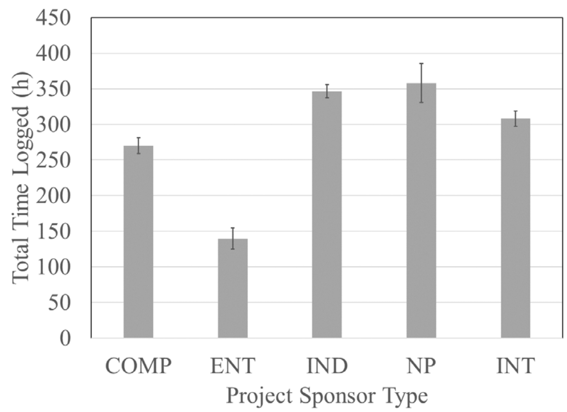

Figure 4. Average total time logged by student teams relative to sponsor/project type, COMP, ENT, IND, NP, and INT.

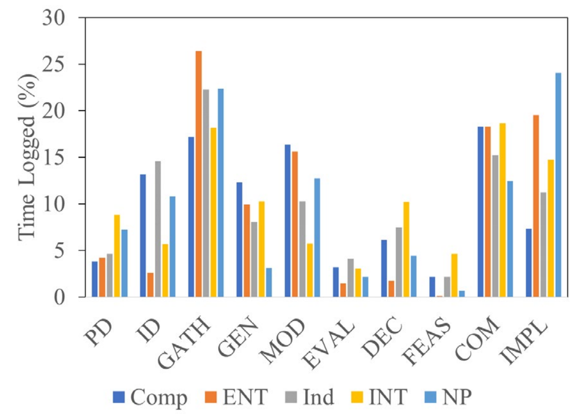

Figure 5. Percent of time logged by activity for project teams on COMP, ENT, IND, INT, and NP projects

significantly different from each other. IND and NP project teams logged significantly greater hours than internal projects (INT), competition (COMP), and entrepreneurial (ENT) in downward succession, i.e., statistically speaking, IND=NP>INT>COMP>ENT.

For the next analyses, we assessed how teams logged hours differently given design activity category. Figure 5 provides additional insight into what activities teams were engaged in as part of their design work. Although variability in time logged in each design category among sponsor types was too high to determine statistical differences between them, data do show differences in time logged among activity types across sponsors.

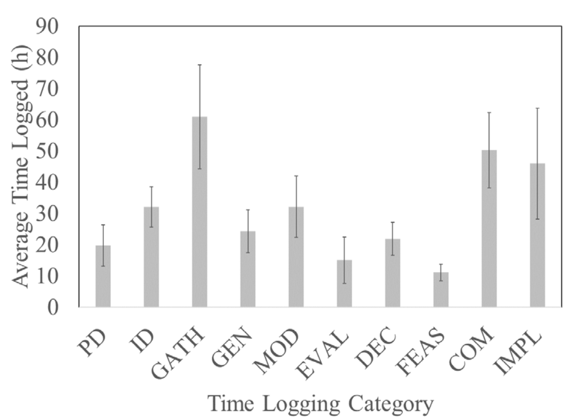

Figure 6. Average total time logged in various design activities including problem definition (PD), identifying needs (ID), gathering information (GATH), modeling (MOD), evaluating (EVAL), decision-making (DEC), assessing feasibility (FEAS), communicating results (COM), and implementation (IMPL).

Observing and comparing average time logged in each sponsor-type relative to design activity, Figure 6, indicates that team spent significantly more time gathering data (GATH), implementing (IMPL), and communicating results (COM) than other categories. One observation to note is that teams spent significantly less time evaluating (EVAL) and ascertaining feasibility (FEAS) than other categories, activities that often occur later in the design process. Despite this, teams showed relatively large amounts of time spent implementing and communicating results. For the former, we reason that teams may rush through later activities to create an implementable final product despite limited extensive evaluation and feasibility testing.

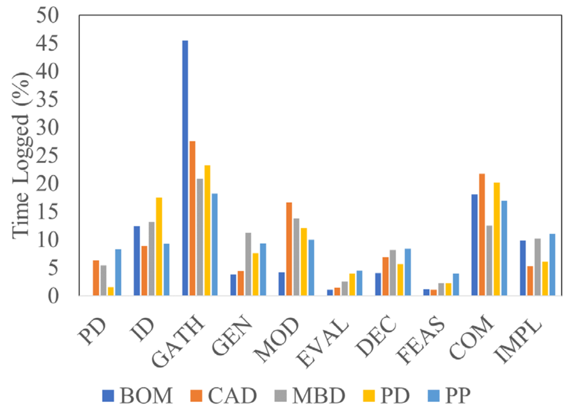

Figure 7. Percent of time spent by students working on projects with the primary deliverable being a bill of materials (BOM), CAD drawings (CAD), a model-based design simulation (MBD), a process design (PD), or a physical prototype (PP).

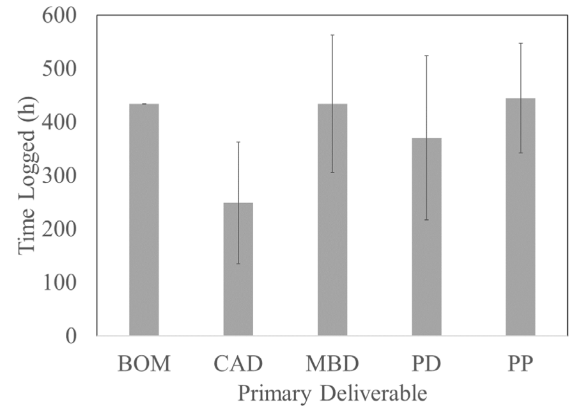

Figure 8. Total time logged (h) by primary deliverable, BOM, CAD, MBD, PD, or PP.

3.2. Effect of deliverable type on hours logged

Figure 7 shows percent of time logged relative to design process category for each primary deliverable type. Although within each design process category, no significant difference exists for different primary prototype, it is clear that teams producing all deliverable types spent more time gathering data and communicating results than for other categories.. This is partly due to the nature of the Capstone Design course which emphasizes data collection to better understand stakeholder needs and engineering requirements and emphasizes constant communication with course participants (instructor and mentor) and sponsor.

On the lower end of hours logged, we saw that individuals spent less time on evaluating (EVAL), decision making (DEC), and feasibility (FEAS). We know that this is due to the timeline of Capstone. Most teams are engaging in these activities late in the process when time must be balanced against developing a minimum viable product to show clients and instructors. “Making it work” trumps other activities. Programmatically, we hope to spend more time on these activities in class and to assign additional (or alternative) work around these categories to ensure students engage in these activities. We are also considering adjusting design process timelines such that teams are able to get to these steps earlier.

Figure 8 shows average total time logged (in h) relative to primary deliverables, BOM, CAD, MBD, PD, and PP. Although the variability is high, the overlapping 95% confidence interval bars confirm that no significant time logging difference exists for teams working to create the various primary deliverables common in our capstone design program. The hope for this analysis was to show that work effort was not reliant on the deliverable type. We strive to promote a capstone design experience for students that does not result in cases of extreme low or high effort. From what is evident in this analysis, time logged did not vary with deliverable type.

3.3. Identification of within-team conflict or struggle based on hours logged

As an example of how team performance connects with the Design Signature, we identified five teams that underperformed in AY24-25 based on the level of within-team conflict we observed, peer evaluations, and based on instructor evaluations of project deliverables. We then compared total time logged by the underperforming teams across time logging categories to the 95% confidence intervals for the mean time logged within those categories for all teams. If underperforming teams' hours logged were below the lower end of the 95% CI, we concluded that the team spent significantly less time on those activities.

As shown in Table 1, the five underperforming teams spent significantly less time on steps in the design process throughout the two-semester course in most cases with one team in particular logging significantly fewer hours in 100% of the time logging categories. A "Y" indicates the time logged was below the lower bound of the 95% CI for the mean of that category.
Given that time logging information was regularly checked, issues with these five projects were clearly recognized early in the design process. These teams received feedback and additional support from faculty mentors and course instructors to work through the challenges and stay on track to complete the projects, and although the teams never regained all the momentum they lost early in the projects, as evidenced by continued lower time logging, they were able to complete their projects successfully. Success in this case is in completing the client-expected project deliverable.

Improvements to consider given the analysis of time logged include closely monitoring teams logging fewer hours and intervening as needed to reduce the incidence of

Table 1. Comparison of underperforming Capstone teams relative to the 95% CI for time logging categories.

Team	**Sponsor Type**	**Below 95% CI – Y/N?**											**% Below Ave.***
		PD	**ID**	**GATH**	**GEN**	**MOD**	**DEC**	**EVAL**	**FEAS**	**IMPL**	**COM**	**TOTAL**	
1	Comp	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100
2	Ind	Y	Y	Y	Y	Y	**N**	Y	Y	Y	**N**	Y	82
3	Ind	Y	**N**	**N**	**N**	**N**	Y	Y	**N**	Y	Y	Y	55
4	NP	Y	Y	**N**	Y	**N**	Y	Y	Y	Y	Y	Y	82
5	Int	Y	Y	Y	Y	Y	**N**	Y	**N**	Y	**N**	Y	73

*Percent of time logging categories for which the team in question logged significantly fewer hours.

4. Conclusions

In this study, time logging data, i.e., the Design Signature, for Capstone Design students working on projects in AY24-25 were collected and analyzed to determine whether the sponsor type, the deliverable type, or both affected the time logged over the 8-month long projects. We also addressed whether a struggling team could be identified based on its time logging data. Findings showed that time logging varied significantly for each case:

1. Industry- and internal entity-sponsored project teams logged significantly greater hours than teams sponsored in other categories although not necessarily across all individual design activities.
2. Project deliverable did not have significant effect on time logging..

3. Teams that struggled due to variety of issues logged significantly fewer hours than average across most design process categories.

Although this study is a work in progress, we are continuing the work. In ongoing work, we hope to show what effect time logging quantities in various activities have on the *success* of Capstone projects and do so with more robust statistics. We are currently working to understand the various success metrics of Capstone projects which could include instructor scores, outside expert scores (tallied at our annual Design Showcase), client/sponsor satisfaction, student satisfaction, and others. We are connecting these outputs to input variables that may impact the outputs in addition to time logged including the interdisciplinarity of projects, the leadership styles of students on teams [9], the deliverables produced, the number and quality of design notebook pages generated, the variability of time logged among teammates, and several others. The goal of this continued work is to identify factors that drive project success and to further develop the Capstone course to promote those factors. Time logging is one factor among many.

We believe that time logging can provide valuable information not only to instructors that seek to understand students' activities and to improve teaching, for instance, giving more time for feasibility testing, time logging is also good professional practice to help students understand their own use of time and to make decisions on how best to spent time to promote success. In addition, the ability to track students' time is extremely valuable for instructors to track progress and to intervene when individuals appear to be contributing less than their teammates.

To conclude, the Design Signature presents a useful method to compare projects and to consider how to improve the delivery of Capstone design.

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