Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #48194

Three Parts to a Comprehensive Way to Describe a System

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Three Parts to a Comprehensive Way to Describe a System

Abstract

Presenting a system/project design to a wide variety of audience is an essential aspect of every project and helps engineers think about their system design from many different perspectives. These perspectives can give rise to several design explorations and ideas to solve the problem. However, describing a system simply but comprehensively does not come naturally to students. It is also one of those coveted intangible engineering skills that students misconstrue as pure presentation skills. This paper describes a systematic approach used to teach student teams in Electrical and Computer Engineering Senior Design at North Carolina State University to describe a high-level system design comprehensively. The paper describes a teaching method that breaks down the system into three understandable and separate parts. Each of these parts has been designed with a specific purpose related to the system, and it looks at the system from a unique perspective. When put together, these three parts work hand in hand to describe the system completely. These parts of the same system also make it easy for students to divide their thought processes into separate perspectives. These parts are (i) Project Concept Diagram/s, (ii) User Operational Flowcharts, and (iii) Functional Block Diagrams. Literature suggests that these charts/diagrams have a unique place in the System Engineering approach. However, in this paper, a table is created with purpose, needed perspective, elements, format, and examples for each part. Authors also point out connections between these three charts and how to create them to work hand in hand to describe the complete system. Such information, when presented to student teams, not only helps them describe their system fully but also helps them understand several requirements and constraints of the system easily and objectively, irrespective of the problem at hand. The paper presents preliminary observations and comparisons on the quality of system description from various design teams to assess the method. It has been observed that such a system description encourages design divergence, which helps design choices be more fitting. This is a work in progress.

1. Introduction and Literature

Literature on System engineering diagrams in many forms is vast [1]-[6]. Though there exist several types of engineering diagrams, models, and types, one thing educators agree on is that a good visual representation of a system is not only necessary for presentation but also improves understanding of the system by all stakeholders [6][14][15]. Teaching appropriate approaches to help students communicate, conceptualize, and thus solve open-ended problems without design fixation is important [10-12]. Several engineering educators have adopted approaches such as early project conceptualization, system maps, visual representations, and graphics design [11-14] to improve project understanding and communication, design decisions, student learning, and more. Literature on many forms of visualization in teaching engineering design to improve problem-solving, and ideation strategies supports the need for structured visualization tools and techniques to help students [14-16].

The Senior Design Program at ECE department at NC State takes a typical product development approach shown in the Figure 1 for their class.

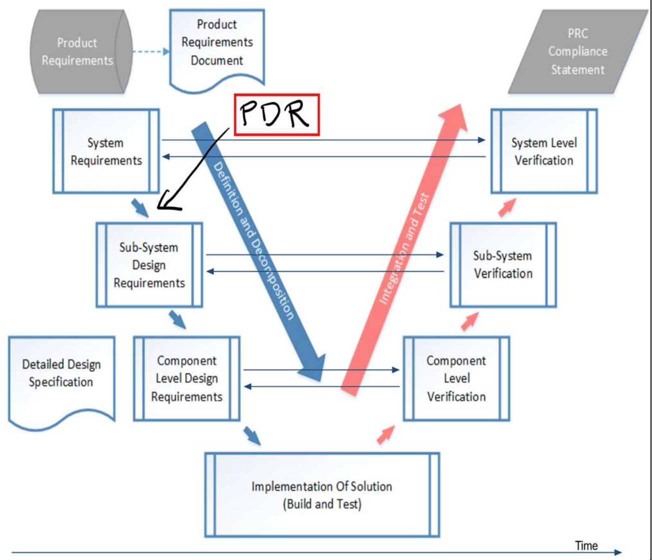

Figure 1: Product Development V curve

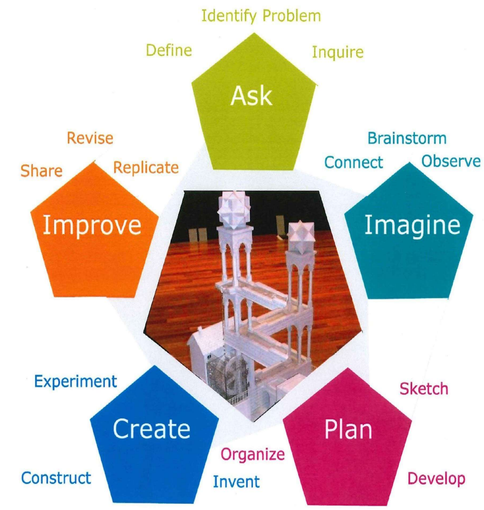

Figure 2: Iterative System Engineering Prototyping Approach

The curve in Figure 2 is supported by iterative Product Development Principles [6] [7]. Students appear for their Preliminary Design Review (as shown in Figure 1 and Table 1) where they are expected to have understood the product requirements and have used them to expand their solution space and to perform tradeoff analysis before choosing the right solution path. Here, we will use the reference, observations, and assessments leading to a Preliminary Design Review (PDR) while describing the Three Diagram teaching approach. Table 1 briefly explains the milestone timeline followed in the two-semester long ECE Senior Design at NC State.

Fall Semester	• Project assignments and team formation (3-5 students/team) • Customer and market research • Explore and brainstorm • ***Design milestones (PDR) – Midsemester mark*** • Status Reviews • Prototype milestones to test the design feasibility (Tech Demo) • Client End of Semester Report
Spring Semester	• **Critical and detailed design Review (CDR)** • Status Review • Prototype demonstration milestones (Alpha Demo) • Status Review • Test, integrate, test (Beta Demo) • Design Expo • Client closure and design handover

Table 1: ECE Senior Design program class milestone schedule over two semesters

2. Challenges Faced by Design Students in developing Preliminary Design

Senior Design projects in the authors' class (final year senior level) have predefined milestones that are used to gauge project progress and design quality. Preliminary Design Reviews are a crucial and first design milestone in this process, where students must present their project goals and requirements, expand solution space, present tradeoff analysis, and present a preliminary plan with the potential to fulfill the requirements. Based on the authors' observations, understanding and thus representing a project holistically during these reviews can be challenging for engineering students for several reasons. The following are based on the authors' observations and supported by the literature on engineering education.

1) Presenting complex systems while balancing technical depth and accessibility: Engineering designs often involve complex systems with many components interacting in different ways. Representing and communicating this complexity in a clear and understandable way is a major challenge [11, 21]. Senior students are generally good at creating highly technical diagrams such as CAD drawings, and schematics once they reach a critical well-defined stage of project design. However, in the beginning phases, students often struggle to communicate high level project concepts while ensuring the material is understandable for variety of audience, which may include faculty, industry professionals, or peers with varying levels of expertise [11]. Striking a balance between technical depth and clear communication requires students to use appropriate analogies, visuals, and simplified explanations for project topics. Using visual aids such as high-level concept diagrams, and user flowcharts can help simplify complex concepts and make the design presentation more engaging and easier to follow.

2) Expanding the design space and addressing design alternatives and trade-offs: Engineering students may feel pressure to demonstrate that their design is not only feasible but also advancing according to the planned schedule. At the PDR stage, students are often in the early phases of design and are expected to compare design approaches and expand solution space rather than create a single prototype design. This can be successfully done if the team focuses on the core product requirements while keeping the user and the system in mind. Students also often face difficulty in presenting and justifying design alternatives and trade-offs due to design fixation [9] and not being able to think of the bigger picture [18]. It can be hard to convey why a particular design choice was made, especially if there are multiple feasible options. A visual way to connect product requirements, user requirements, and system design is an important tool that can help [14-16].

3) Breaking down and integration of subsystem: Many ECE capstone design projects involve interdisciplinary work, e.g., electrical engineering, mechanical design, and software development. Students may have difficulty breaking the system down into logical and workable subsystems and showing how their work integrates across these aspects and how different components interact within the overall system in the overall design. A hypothesis is that a well

thought high level system architecture that includes block diagrams, flowcharts, can help break the system down into workable subsystems and also convey interconnectedness of the project.

4) Time Constraints Challenge: PDRs are typically time-constrained, and students may struggle to present their work in the limited time available. A visual way to present key points can be a good tool.

After observing and studying system engineering literature [1-6, 13, 15, 16, 19, 21], the following three areas were identified as the areas where visual representations could be most useful for Electrical and Computer Engineering students to present and thus understand their high-level requirements of the project holistically. (i) Visual representation of the Project Concept, (ii) Visual representation of high-level users and system Operation, (iii) Visual representation of high-level project technical description: The following section describes the three diagrams, their purpose, and interconnections to address the challenges in this section. We refer to these challenges in the later section of this paper, explaining how and to what extent these are solved using the three diagrams.

3. Description and Purpose of the Three Parts method

The three diagrams described here are not novel and have been part of the System Engineering and Product Development process for decades [1-6]. We are summarizing their use in students' senior design projects to teach them system design and visualization. Introducing and teaching these drawings in a structured manner to engineering students helps them improve their project designs, present them, visualize them, and thus understand them. These drawings are asked to be created as a tool for project design. Descriptions also connect the purpose of each drawing to the four challenges stated in previous section.

(1) A **Project Concept Drawing** (PCD) is a visual representation of the initial design ideas or concepts for a project, often used in the early stages of the design process. Its purpose is to provide a clear and simplified view of the proposed solution or system to communicate the project's main features, overall structure, look and feel, and function. These drawings help stakeholders—whether designers, engineers, or clients—understand the vision and scope of the project, even if the details are not yet fully developed. These drawings are also used to quickly represent multiple solutions to a given problem, compare them, and perform a high-level trade-off analysis. Concept drawings also help all stakeholders quickly provide feedback and opinions on the pros and cons of various approaches. These can be considered early mockups before physical mockups are created. PCDs are specifically helpful in addressing challenges 1, 3, and 4. PCDs can be used as visual props while explaining the different technical and interdisciplinary aspects of the project from the user's perspective. They also help in quickly explaining the expected project outcomes as they can be illustrated as mockup drawings. See Appendix for more examples.

(2) A **User Operational Flowchart** is a visual representation of the steps or processes that the end-user follows while interacting with a system, application, or product. It shows the sequence

of actions or decisions a user makes, from the start to the end of an operation, and often includes the different paths a user might take depending on their choices or inputs. The purpose of a user operational flowchart is to map out and simplify the user experience (UX) and the flow of tasks, helping designers, engineers, and stakeholders understand how users will interact with a system. UOF can be helpful in addressing challenges 1 and 2. They help all stakeholders agree on how the product or system is expected to be used by the end user, user features, and ease of use irrespective of the technical depth of the solution. This enables a exploratory discussion amongst the stakeholders about various ways to achieve the same high-level user experience expanding the design space.

(3) A **System Functional Block Diagram (FBD)** is a graphical representation of a system's major functions and their relationships, typically used in engineering and systems design to break down a complex system into simpler components or modules [6-7]. It provides a high-level overview of how different subsystems or components interact within the system to achieve a particular objective. Each block in the diagram represents a specific function or process, and the connections between blocks indicate the flow of information, materials, or control signals. FBDs are helpful in addressing challenges 1, 2, and 3 since they bring technical depth as well as the interconnectedness of different project aspects together. FBDs also highlight connections between different interdisciplinary aspects of the project and the user. The FBD is a very useful tool for defining the interfaces between subsystems, this allows a more obvious way to break up the project among the team members and define how the subsystems communicate with each other.

The Three Diagrams together help address challenge 4 as they can be used as high-level visual tools in explaining different aspects of the projects clearly.

Table 2 below explains their roles in system design and how they are interconnected. The interconnectedness of the drawings helps make them comprehensible for variety of audience. This is further explained in the next section through in-class case studies and examples.

Project Concept Drawing (PCD)	User Operational Flowchart (UOF)	Functional Block Diagrams (FBD)
The product's external look and feel	How a user will operate it	Engineering block diagrams with functions
<u>Role in the System Design</u>		
The concept drawing serves as the first step in system design, illustrating the components or subsystems in	The user flowchart focuses on how a user will navigate through the system, which directly relates to how they	The System Functional Block Diagram focuses on the "behind-the-scenes" operations of the system.

a simplified, tangible form. It provides a foundation for understanding what the system will physically and conceptually look like, laying the groundwork for both the **user flow** and the **functional blocks**.	will interact with the components shown in the concept drawing. Each step or decision in the user flow corresponds to an operation or interaction with one or more functional blocks in the system. For example, if the user initiates a task (like pressing a button), this can trigger a particular function (e.g., sending a signal to the controller or activating a motor).	Each functional block in the diagram represents a specific process or system function that corresponds to the user's actions in the flowchart. For instance, when a user performs a certain task in the flowchart (e.g., entering data), the functional block diagram shows how that task triggers internal processes (e.g., data validation, processing, and response generation).
Drawing of several to expand the solution space is encouraged.	Exploration of different types of end-users the system may have and draw different charts from each user type's perspective. E.g. designer, admins, maintenance users, customers.	Identifying several functions, the system must perform, based on concept chosen and user involved. Each block can be further broken down into more refined functional blocks creating an iterative approach to design.
<u>Association of Diagrams with Stated Challenges in Section 2</u>		
PCDs are helpful in addressing challenges 1, 3, and 4, since they can be used as visual props while explaining the different technical and interdisciplinary aspects of the project. They also help in quickly explaining the expected project outcomes.	UOF can be helpful in addressing challenges 1 and 2. They help all stakeholders agree on how the product or system is expected to be used by the end user, user features, and ease of use irrespective of the technical depth of the solution. This enables a exploratory discussion amongst the stakeholders	FBDs are helpful in addressing challenges 1, 2, and 3 since they bring technical depth as well as the interconnectedness of different project aspects together. FBDs also highlight connections between different interdisciplinary aspects of the project and the user.

	about various ways to achieve the same high-level user experience expanding the design space.	
<u>Connecting the diagrams for comprehensibility:</u> (1) All diagrams shall represent the significant physical aspects of the system. Identify separate high-level aspects of the system and find a way to highlight them in all three drawings. These aspects could be separate physical aspects or interdisciplinary aspects which need to be integrated in the project. (2) User actions described in UOF must be visually representable through PCD. Users shall be able to understand how the actions described in UOF are possible by looking at the PCD. (3) FBD shall include interfacing details and functional blocks that make the actions in UOF possible and support the system features described in PCD. (4) All three diagrams shall highlight the major and core requirements of the project. (5) All three diagrams shall include the environment or setup in which the system is expected to operate, the user, and any other external factors that impact the system's operation.		

Table 2: Description of the Three Diagrams.

4. Implementation in Educational Setting

Authors have taken the pedagogical approach of teaching (case studies, workshops, in-class exercises, and examples), defining a deliverable and rubric, providing feedback, and gathering learning lessons.

First, students are provided with out-of-class readings explaining the definition, purpose, and usage of these diagrams and their role in system design and development. Out-of-class material consists of slides with tables, examples, diagrams from previous years, system engineering articles and publications, and expert videos. These materials, especially examples, can be modified based on the project cohort of each year. Additional tools, such as morphological matrices and mind maps, are provided to the students to aid the brainstorming process. There are two active team workshops held in class (75 minutes each) in which student teams do the following activities:

(1) Workshop 1: Project Concept brainstorming to increase the solution space. This workshop also provides several brainstorming techniques based on idea generation techniques workshop presented in Capstone Design conference 2018 [20],
(2) Deliverable: First Concept Drawings: Create at least 40 to 50 concept drawings exploring their possible solution space based on the high-level project requirements for their project.
    (a) Rubric and feedback for First Concept Drawings: Instructors assess and provide feedback on these initial concept drawings using two separate aspects defined in the

rubric: (1) Variety and divergence among the drawings: Have the students explore a wide range of approaches and expand their solution space. The majority of the feedback is to point out other solution possibilities and research new approaches. (2) Comprehensibility and completeness of the concept drawings. This aspect involves understanding whether the concept drawing covers all aspects of the project, including the user operation, the system's normal operating environment, proportionality and scale, physical location, accessories, etc.

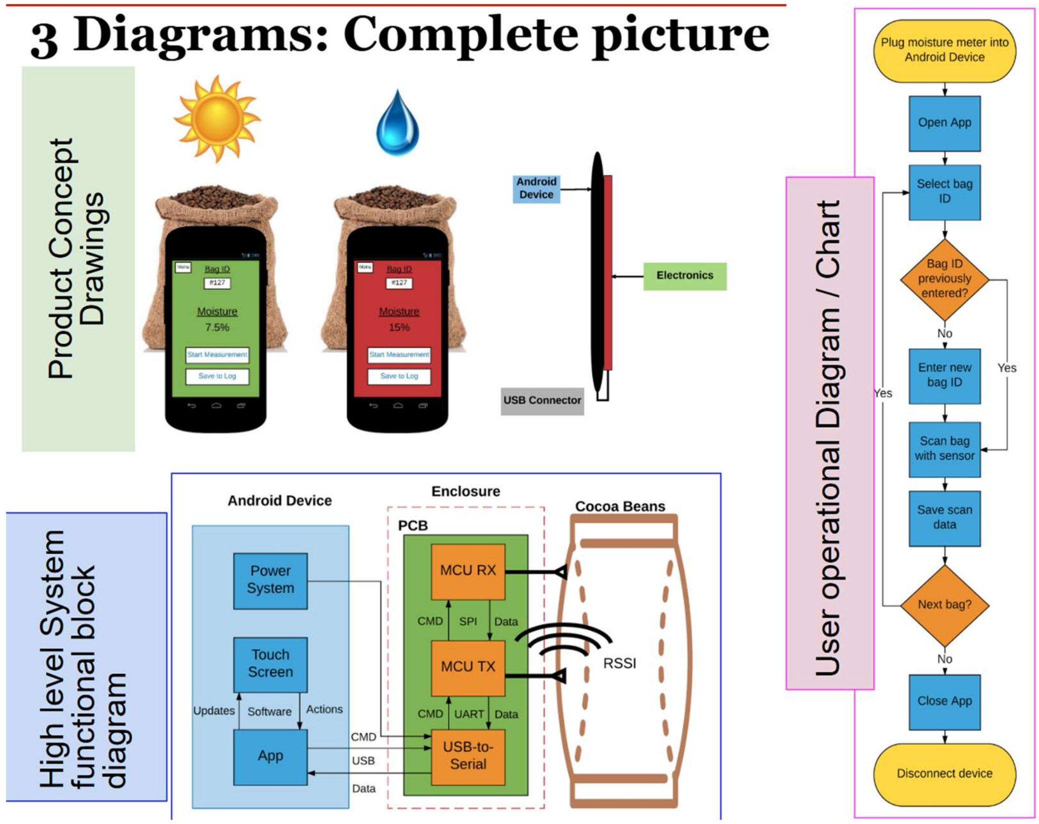

Figure 3: Case Study Example of a Previous Project

(3) Workshop 2: Comprehensibility and Interconnectivity of the Three Diagrams

(a) Case studies of the previous projects with their diagrams: One example of the case study is in Figure 3. Students are shown several "Three Diagrams" examples in class and report briefly on their understanding of the project based on the Three Diagrams shown. Students are able to describe the goals of the case study projects highly accurately just by observing the Three Diagrams. E.g. In Figure 3, students infer that it could be a project to create a hand-held device to detect moisture levels in cocoa bean bags, which is correct. After giving it some thought, some high-level requirements are automatically highlighted by these three diagrams. Some of the ones students report are, "Device should be handheld," "It should be non-invasive," "simple to use," "Should work with Android," etc. This exercise gives them an insight into how to create these three diagrams for their project to represent its high-level design and core requirements clearly.

Explanation of the Connectedness of the Three Diagrams from the case study is done in class, highlighting the points explained in Table 1. There are three main aspects of this project: a cocoa bean bag, an Android device, and an electronics board (PCB). All three diagrams include these three components, connecting the diagrams to understand the project requirements and usability. The Android app screen shown in the PCD creates a visual representation of the user actions explained in the UOF. FBD clearly explains how functionality will be divided between the Android app and the PCB and high-level technical solutions on how the system will interact with the cocoa bean bag. Most importantly, all three diagrams highlight the three core requirements of the project, which are a **hand-held device**, **non-invasive** operation, and an easy-to-use **moisture meter**.

(b) In-class exercise: Following the case study discussions, this workshop includes a guided in-class exercise in which all teams are provided with a short list of example requirements and are asked to draw "Three Diagrams" to represent the project using the concepts described in Table 1 and highlighted during the case study. After the exercise, the diagrams are discussed in class for their connectedness, usefulness, presentability, and comprehensibility.

(c) Brainstorming sessions within the team to create several different diagrams to represent their project holistically. Compare and contrast their diagrams within the team and sometimes with a peer team.

(4) Deliverable: System Architecture Document: Define 4 to 5 detailed PCDs based on the instructor's feedback from the 40 to 50 previously created first concepts in Workshop 1. Add UOF and an FBD representing the concepts and functionality and fulfilling the refined product requirements. Analyze trade-offs of the solution space against defined user operations. Students are given a document template and rubric to get them started with design divergence (included in the Appendix). The template forces students to compare the concepts in several different perspectives while retaining the high-level user experience and system functionality defined by core project requirements and represented by UOF and FBD respectively.

(a) Feedback: Instructors provide feedback on all three sets of drawings and the system architecture using comments and suggestions to point out missing parts, and any need for extra explanation.

(5) Workshop 3: Identifying defining features of the Three Diagrams that relate to each of the core product requirements. Discuss within the team, modify the diagrams, and add the features as part of the trade-off analysis table to expand solution space. Break down the system into subsystems creating lower-level subsystem diagrams. Repeat the same process for each subsystem. This encourages iterative approach to design and prototyping.

(6) Deliverable: Preliminary Design Reviews: PDRs are scheduled after Workshop 3. Each team is given 20 to 30 minutes to present their high-level system design, subsystem design options,

design trade-offs analysis, preliminary project plan and project budget. A detailed instructions and rubric used for PDRs is included in the Appendix.

5. Preliminary Assessments

Preliminary assessments are from a class of 237 students (58 separate project teams) over three different project deliverables which involve preliminary system design elements.

(1) First Project concept drawings (40 to 50 PCDs per project): This was assessed after Workshop 1, and the average score was 85%

(2) System Architecture Document: All teams are provided a basic template to organize the architecture document. The template is linked in Appendix. This included all three drawings after Feedback 1 and Workshop 2. Average score for the high-level design is 88%. Average scores for the Three Diagrams PCD, UOF, and FBD, respectively were 84%, 91%, and 89%. All teams were provided feedback on their Three Diagrams as part of the architecture document. Score for solution tradeoff analysis was 83.33%

(3) Preliminary Design Review: Average score for PDRs (which includes design beyond three diagrams and project plan elements) was 89.4%. High-level system design was assessed as part of PDRs using modified and improved Three Diagrams and other design details based on them. The average high-level design score was 93%. The average score for tradeoff analysis 89.2%

(4) Critical Design Review: This design review takes place near the beginning of the second semester. Teams are expected to have solid high-level system design and a detailed knowledge of subsystem design by this review. By CDR, teams expand iteratively on the initial Three Diagrams created before PDR. The scores of CDR are included here to show the design progress, which is founded on the Three Diagram.

Table 3 below explains the instructional sequence and score improvement timeline. Detailed rubrics for all deliverables can be found in Appendix. The scores are separated in the attempt to assess how different challenges stated in section 2 are addressed

Deliverables/	**Overall Average score (Challenge 1-4)**	**High-Level Design Score (Challenge 1, 3, 4)**	**Design Trade-off and subsystem design Score (Challenge 1, 2, 4)**
- Workshop 1			
First Project concept drawings (PCD)	85%	85% (PCD)	Not assessed
-Feedback on PCDs -Workshop 2			

System Architecture Document (Three Diagrams assessed separately)	88%	88% (PCD: 84%, UOF 91%, FBD: 89%))	83.33%
-Feedback on System Architecture Document -Workshop 3			
PDR (High-level design and subsystem tradeoff assessed separately)	89.4%	93%	89.2%
Critical Design Review	***91%***	***94.1% (refined high-level design)***	***91% (subsystem design)***

Table 3: Instructional sequence and score improvement over time.

6. Qualitative and Quantitative Improvements

Teams' project deliverable scores are observed to improve from the first deliverable onwards. Authors also observed improvement in students' ability to communicate the project design with their stakeholders. The performance on PCD as well as the Three diagrams, was significantly improved from workshop 1, workshop 2, and instructor feedback cycle, helping most teams to well represent and understand the high-level system design in their PDR. It is also clear that teams struggled more with Project Concept Drawings than User Flow Charts and Functional Block Diagrams.

7. Challenges solved with Three Diagrams

The four main challenges listed in the earlier section 2 were assessed after introducing the Three Diagram project representation approach.

Challenge 1 and Challenge 3, Balance between technical depth and accessibility to any audience and explain the interconnectedness between interdisciplinary aspects of the project: All teams were advised to use these diagrams as part of the high-level system design introduction. Improvement in the overall High-level system design score suggests improvement in challenge 1. FBDs helped teams break the system down into logical subsystems based on connections and functionalities of each block, improving the subsystem design score.

Challenge 2, Expanding design solution space: This is assessed by the Design trade-off scores and shows significant improvement.

Challenge 4, Time constraint. The timeliness of the project was not assessed separately however, teams' PDR scores are directly related to how much information they were able to present clearly in the given time.

8. Challenges with the Teaching Method and Possible Improvements

(1) Examples help or do not: Case study examples are picked from the best projects from the previous years. The case study survey emphasizes the point that Three Diagrams drawn well can describe a project for any audience and help as a preliminary step towards expanding solution space. However, many teams think they need to comply with the examples shown, hindering their creativity in trying new concepts for their projects. All projects are different, so teams who are looking for things in the examples that relate to their project, in some cases, are disappointed and believe that none of the examples are useful for them, missing the high-level point. We plan on creating separate cohorts of teams and running separate workshops, one with case study examples more relevant to each cohort.

(2) What is intuitive: User flowcharts are always more intuitive to the students, closely followed by FBDs. PCDs are the last on this list. Students struggle during the brainstorming sessions, hitting mind blocks to come up with several concepts. This has been observed by other engineering education researchers as well [18]. Providing them with brainstorming tools and prompts has improved their performance [20]; however, students miss the iterative approach of the process unless it is incorporated during in-class activities. Teams struggle to brainstorm outside of the classroom during team meetings or team lab sessions. They also perceive concept diagrams as creative drawings rather than engineering drawings. Some comments received are "I am not good at drawing", "How much detail is enough detail?" and "How do I draw based on the rubric." Students take these drawings more as an assignment than something that will help them design and understand the project better. This hinders creativity as they are trying to comply with the rubric. Offering shorter in-class activities followed by instructor feedback loop can be beneficial.

(3) Gauging rubric-based vs. real understanding of the project: The scores identify the improvement in students' performance defined by the rubrics of each deliverable. To understand the qualitative improvement in students' design learning and project understanding, we plan to take an assessment approach with project-based quizzes, student surveys, sponsor surveys, and peer surveys.

(4) FBD details: A Functional Block diagram should be constructed in a logical way, giving great thought to the flow and communication between the blocks and how the subsystems interact. The hierarchy of the systems should be clearly defined, as should the delimitation between the subsystems. The mistakes we see teams making in the Functional Block Diagram are:

a. Little understanding communicated of the high-level functionality
b. Poorly named blocks and signals
c. Text so small that it cannot be read
d. Poor use of colors and shapes to help the communication i.e. use colors and shapes to delineate between the high-level bocks and the subsystems, color code signals to indicate power, data, mechanical,etc. flow

e. Not indicating what parts of the system your team is working on and what parts of the larger system the team will not work on
f. Poor logical layout
g. Poor understanding of interfaces and how to break down and indicate them on the FBD

Many of these issues may be resolved by offering a separate in-class workshop on FBDs as well as offering guidance on dos and don'ts of FBDs.

(5) Workshop impact vs. class size: This challenge encompasses other challenges within it. This study has been done in large classes (237 students/58 unique project teams). Several workshops offered in class require active participation of students with their team as well as active participation in class to follow the prompts. Offering the workshops to smaller sections of projects where projects are broken down based on technical and application similarity might be beneficial. Case studies as well as in-class exercises could be picked based on each section's theme.

9. Summary and Conclusion:

A **Project Concept Drawing**, **User Operational Flowchart**, and **System Functional Block Diagram** are three distinct, yet interconnected tools used in the design and development of a system. These diagrams serve different purposes, but they can be effectively integrated to provide a comprehensive understanding of the system's design, functionality, and user interaction. A systematic approach to teaching how to use these diagrams has shown potential in improving students' understanding of their own projects and communicating it to all stakeholders. It also has helped them expand the solution space over time. Students' high-level project design scores have also shown improvement, leading to Preliminary Design Review when these Three Diagrams are used as tools to represent and understand the project.

10. Next Steps

The authors have realized several next steps in the aspects of instructions and assessment. We plan to create toolboxes with and without previous project examples and assess and compare their understanding of the Three Diagrams. Within the toolboxes, more tools will be provided to help the students brainstorm, create, and break down design problems into logical elements. Some workshops will be broken down into themed project sections to be able provide more relevant case studies and examples as well as to encourage more student participation in the workshops. Short peer surveys and quizzes will be added to assess students' understanding of the diagrams over several milestones and how that relates to the Three Diagrams approach. Similar surveys will also be done with student peers, external audiences and other stakeholders of the project to measure qualitative improvement in project understanding, communication as well as design learning.

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Appendix

(1) First Concept Design rubric:

1. Variety and Divergence	Drawings shall cover the full scope of the project as defined by the sponsor on the project website and completed meetings. Full points will not be given for small variations of the same theme. The goal is to explore radically different themes. Expectation is to have approximately half of the solutions as safe linear progressions of the design space, and the other half as radical ideas that you do not see completely working based on your current engineering skills. Radical ideas must still be relevant, for example, a mouse trap based on a Saturn V rocket is too radical.	50
Variety and Divergence Deductions	Good variety with minimal radical ideas	-5
	Some variety but no radical ideas	-10
	Minimal variety	-15
2. Completeness	All drawings must have correct labels, a rough scale (if relevant) to show the system's form. It should represent either the whole system or a clearly defined aspect of it. It should show relevance to how the user will use it. Full completeness points will not be awarded if less than 10 drawings per team member are provided. No points will be lost for bad artwork or poorly sketched drawings if they communicate the concept and are complete, the goal is to get ideas recorded.	50
Completeness Deductions	Somewhat complete labels (per sketch)	-0.5
	Few labels (per sketch)	**-1**
	No labels and drawing not obvious (per sketch)	-3
	Relevance not captured (per sketch)	-1
	Less than 10 sketches submitted per person (per 10% missing)	-5
	Poor organization of submission	-5

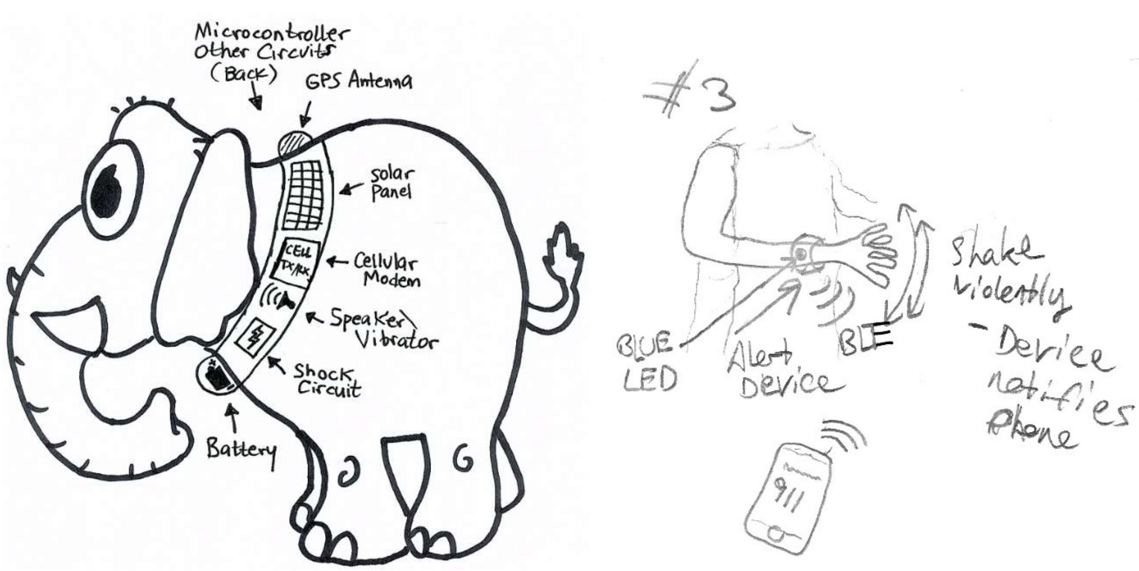
(2) System Architecture Document Template with Instructions provided to the students is published here.

(3) Preliminary Design Review Rubric

Element/ Slides	What to present	Grade
1. Project Introduction (30 sec - 1 min)	Project title, Team members, Sponsors & Mentors, Background. Major / Key Product Requirements (Clear and Concise), Key constraints if any.	**5**
2. High-level System Design (12 min)		**15**
a. Project Concept Drawing	Concept drawings for selected system architecture/solution. Briefly mention the pros and cons of high-level design challenges.	5
b. Functional Block Diagram	High-level block diagram highlighting all subsystems and explaining high-level system functional flowchart.	5
c. User flow chart of the overall system	Complete method of setup, operation, and debugging from the user's perspective	5
d. Subsystem breakdown and Trade-off		**35**
d.1 Detailed subsystem block diagram	Detailed block diagram showing the functional design of each subsystem	5
d.2 Design Challenges and Subsystem Functionality	Briefly list design challenges and subsystem functionality for each subsystem. You may use flowcharts or explain functionality using the block diagram.	30
d.3 Design alternatives for each subsystem and tradeoffs	Present tradeoff-tables for components/tools/methods/solutions/softwares/platforms /algorithms for each aspect of every subsystem and its parts. Highlight the pros and cons of various options and show the selected choice.	
d.4 Components and parts selection and tradeoffs	High level component / parts selection options and tradeoffs tables for each subsystem or method or tools.	
3. Overall Project plan and Detailed Tech Demo plan	Explain (i) Roles and Responsibilities, (ii) Project milestone timeline and (iii) Estimated project budgetsExplain your tech demo plans in detail. Tech Demo is your first technical prototyping milestone where you will prototype various designs to assess	**20**

	feasibility.	
4. Mock-up Product Demo (4-5 min)	Present mock-up of various aspects of the project: Device mockup, UI mockup, setup/installation mockup, etc. Make sure to walk through user operation, explain sizing, materials, component placements and mounting as necessary.	**15**
5. Project Health and Design Quality	Does the project design demonstrate maturity, applicability, and quality? Has the project made sufficient progress relative to what could be reasonably expected?	**10**

Some of the Project Concept Drawing Examples presented in class:



Appendix Fig 1: One of the concept drawings for "Tracking Wild Elephants". Second picture is to describe the concept of "a wearable device which can help joggers to send an immediate alert in case of emergency"