
Underlying Design Motivations in Design Methods and Outcomes

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- **Explicit design goals** – directly dictate the design methods and outcomes
 - Initiated by the consumer, end user, or sponsor
 - Basic information on:
 - Function
 - Form
 - Use
 - Act as guidelines for the designer
 - Soft data that drives the direction of the design process and the design outcomes.
- **Underlying design goals** that strongly and passively influence the design methods and design outcomes [1].
 - May or may not be explicitly expressed
 - Occur as a result of the **design motivations**:
 - Individual designer
 - Team
 - Organization
 - Also influences how the designer translates the design to the end user [2-3].

- The **design process** is the methods used to develop a design
 - It is an iterative process
 - Five widely main steps in the design process [4-6]:
 1. Clarification of Tasks
 2. Concept Generation
 3. Design Requirements
 4. Embodiment Design
 5. Detail Design
- Underlying motivations will not influence the steps taken but influence what is conducted and what tools are used within these steps
- Also influence:
 - Design outcome
 - Design translation
- It is known that underlying motivations has an influence design, however, the magnitude is not understood [7]
 - Dynamics of the design motivations
 - Where it is reflected?
 - How to capture the underlying influences?
 - Are there trends?

- **Objective:**

- Identify where and how underlying design motivations influence:
 - Design process
 - Design outcomes
 - Design translation

- **Motivation:**

- Pinpointing where in the design process underlying motivations are most and least influential and who is the major contributor, will provide a better understanding on the effects of these motivations on the use of the design process and tools.
- **Design for the Environment (DFE)** and **Design for Manufacturing and Assembly (DFMA)** are two common design cultures [8-15]
 - To what degree does this influence the design?
 - Is a personal influence or an organizational driven influence?
 - Which influence is stronger?
 - Can this potentially be mapped to predict the design outcome in an automated way?
 - How and where designer culture influences the design methods, outcomes, and translation can be evaluated if two distinct design cultures are given similar explicit design goals?

- If the main steps used in the design process are common for all designers, and the explicit design goal is the same, but the underlying culture of the designers is different, the impact of the culture will be reflected in the common aspects of a design
- All designs undergo
 - Design process
 - Final design or design outcome
 - Translation of the design
- If there is an underlying influence that drives the designer or design team, will it be reflected in these common aspects? [14-17]
 - Use of analogies in the design process
 - Considerations for DFE/DFMA
 - Use of analogies to translate the design
 - Effectiveness of the analogies in design translation

- A case study was conducted of an upper level undergraduate Mechanical Engineering design course to evaluate the impact of design motivations on:
 - Design methods
 - Design outcomes
 - Design translation

Table 1. Class B Teams and Associated Target Grade Level and Design Focus

Team	Grade	Focus	Team	Grade	Focus
Purple-01	2nd	Forces, magnets, and solids & liquids	Orange-06	5th	Forces and Motion
Purple-02	5th	Forces, friction and impulses track	Orange-07	4th	Forces and Motion
Purple-03	5th	Pushes and Pulls	Orange-08	5th	Pushes and Pulls
Purple-04	2nd	Pushes and Pulls	Orange-09	4th	Irrigation System for Future Greenhouse
Purple-05	5th	Forces and Collisions	Orange-10	7th	Renewable Energy

- Course:
 - Class A (MW)
 - 11 teams
 - DFMA underlying influence from professor
 - Class B (TTh)
 - 10 teams
 - DFE underlying influence from professor

- Explicit Goal:
 - Partnered with one grade school teacher (2nd to 7th) and provide the class with a design that teaches a lesson from the teacher's science curriculum.

- Course consisted of a lecture and design review weekly once the project began.
 - Design review teams would formally present on their design status (goals, requirements, future plans, feedback)
- Class B's design reviews were observed
- A design expo put in place by Steven O'Shields was used as an opportunity to explore the effects of DFMA/DFE
 - Undergraduate students showcased their designs to the grade school students.
- Two themes were evaluated:
 - The use of analogies in the undergraduate student's design methods, outcomes, and the way they translated the design to the grade school students.
 - Surveys (Grade school students and Undergraduates)
 - The influence of underlying design motivations in design methods of the students.
 - Tallying DFE mentions
 - Surveys

Design Course

Class	Team Participation	Percent Team Participation	Student Participation	Percent Student Participation
Class A	8 of 11	64.64%	25 of 67	37.31%
Class B	10 of 10	100.00%	48 of 60	81.67%

Grade School Students

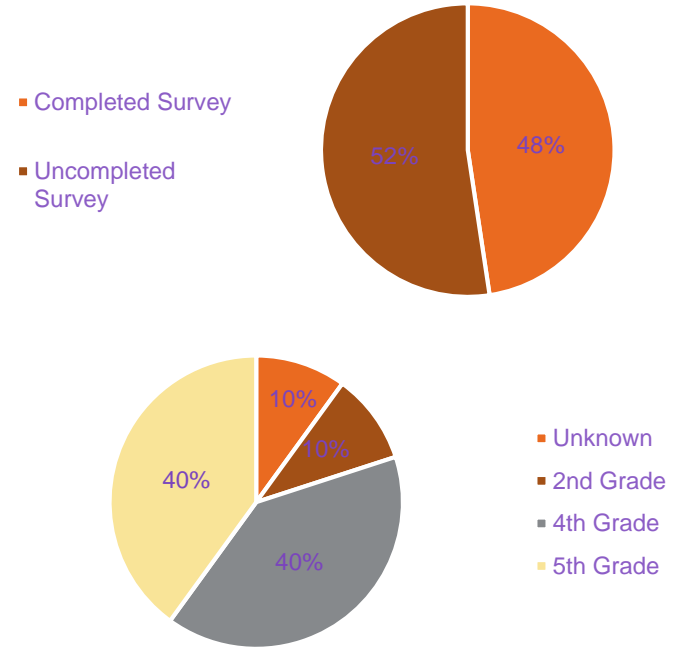


Figure 1. (TOP). Percentage of completed and uncompleted grade school surveys. (BOTTOM). Grade coverage of completed grades school surveys.

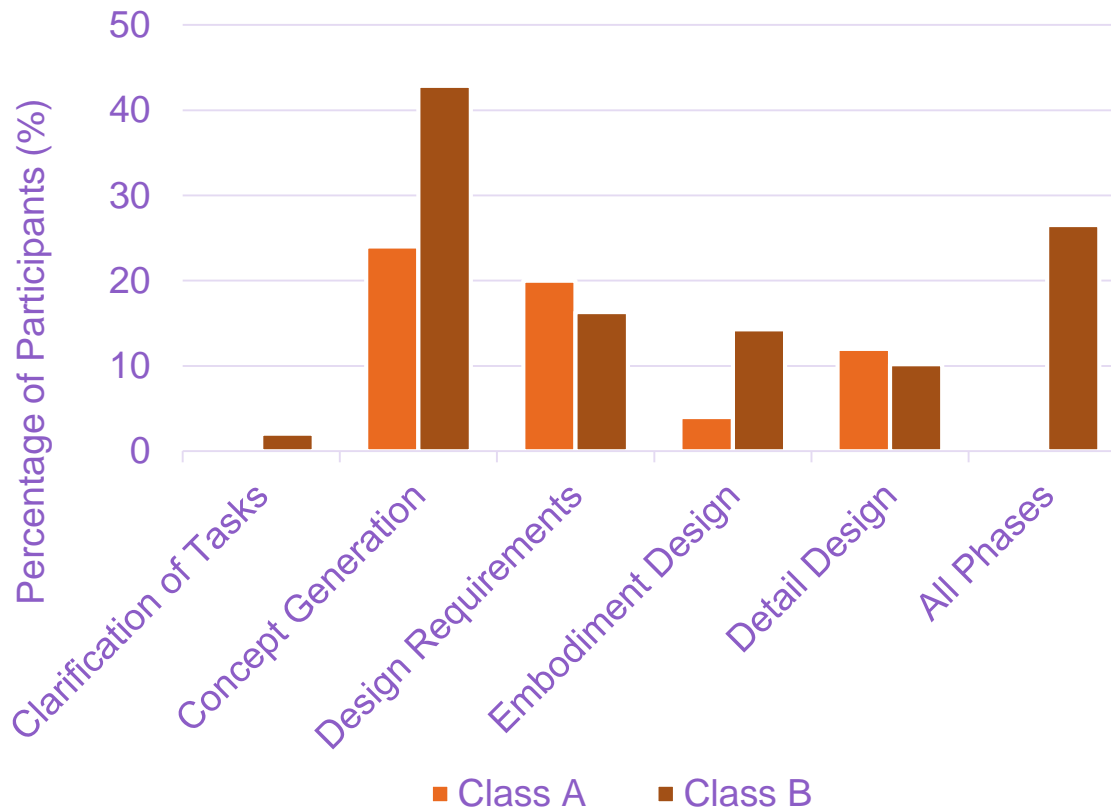
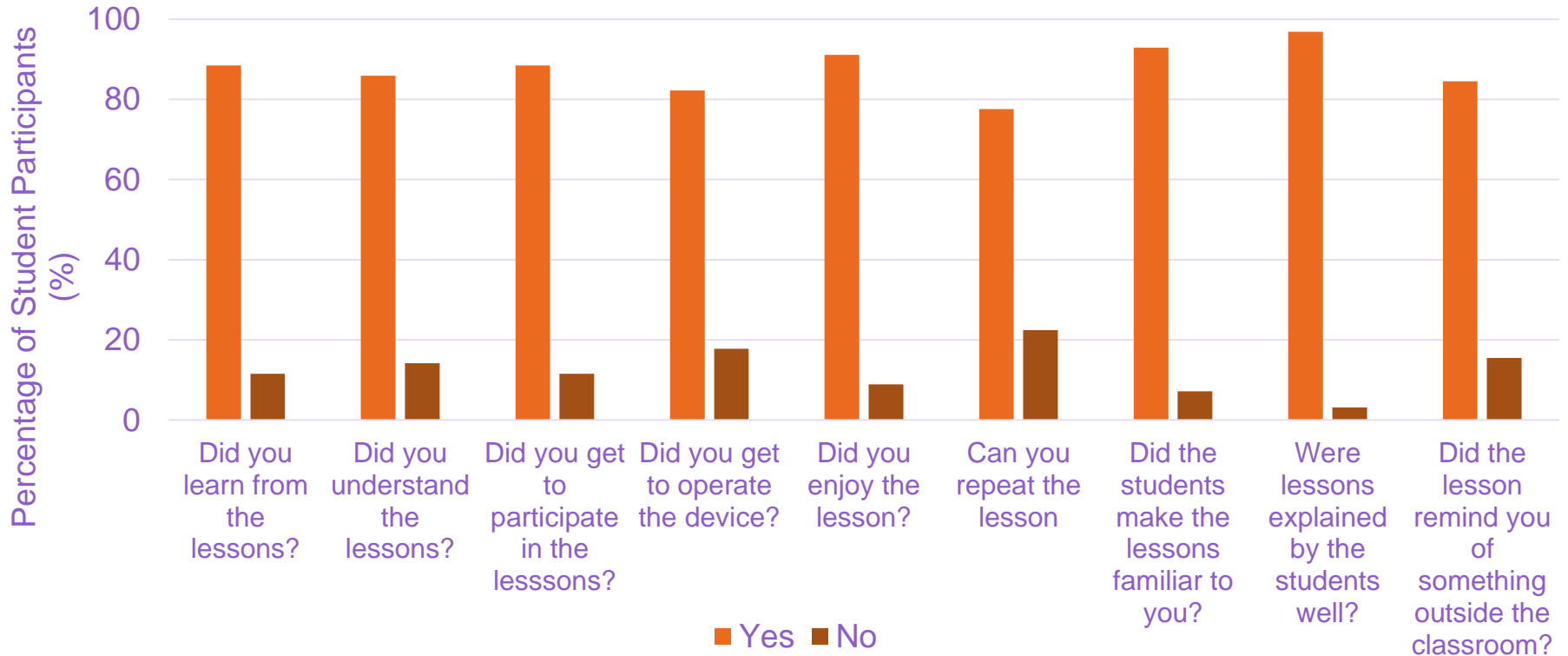


Figure 2. Percent of participants that indicated when analogies were used in the design process for Class A and Class B.

- **Class A** - 68% did not use analogies
- **Class B** - 51% used analogies
- Majority of the analogies were used in the concept generation phase
- Greater number of students in Class B used design analogies in all phases of the design process
- Design **form/function**
 - Class A 72% did not use analogies
 - Class B
 - 51% in function
 - 78% not in form

Figure 3. Percent of Yes and No answers from the grade school student survey.



- Students used analogies to translate the design lessons to the grade school students.
- Analogies were effective in helping the grade school students understand the lesson and retain the information.

- Design Reviews and DFE occurrences

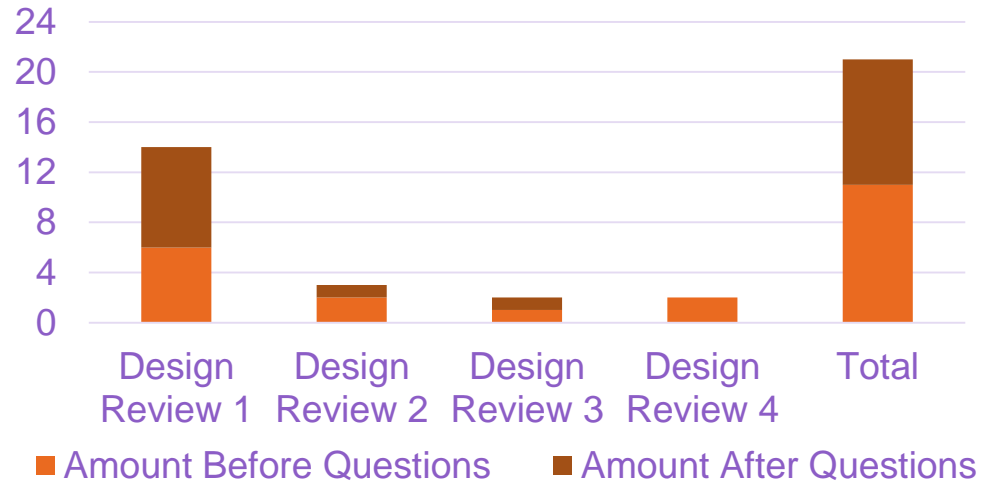


Figure 4. Occurrences when Class B mentioned DFE in relation to their design during design reviews.

- Earlier in the semester, more teams mentioned DFE which revolved around materials
- Mentions decreased when they stopped explaining why they chose materials
- Key words
 - "Reusable, recycling, reuse, minimize life cycle, consumable, sustainable design, minimize environmental impact, recycled wood, recycled materials."*
- A decrease in DFE mentions suggests that there are underlying design influences in the group that will not be formally expressed in external presentations.
- At the later stage in the design DFE became common knowledge with no need to be shared.
 - Evaluated with surveys

- To evaluate if the engineering design students considered DFE or DFMA, they were surveyed on their use of DFE and DFMA as well as the influences that encouraged them to use DFE or DFMA.

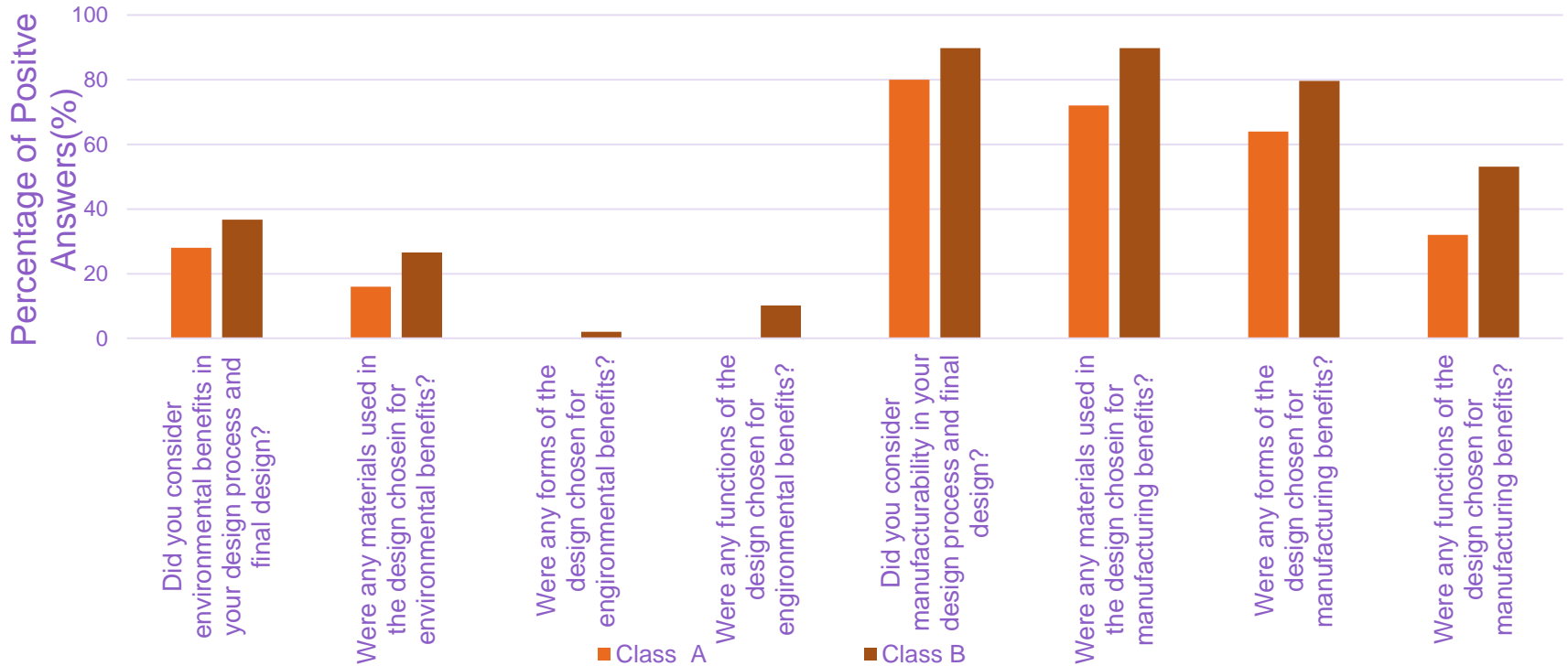


Figure 5. Percent of Positive "Yes" Answers to Survey Questions on DFE and DFMA for Class A and Class B

- Indicative that the DFE and DFMA influences from the professors was reflected DFE/DFMA considerations of the students

- When DFE/DFMA was used in the design process for Class A and Class B was evaluated as well as the influences

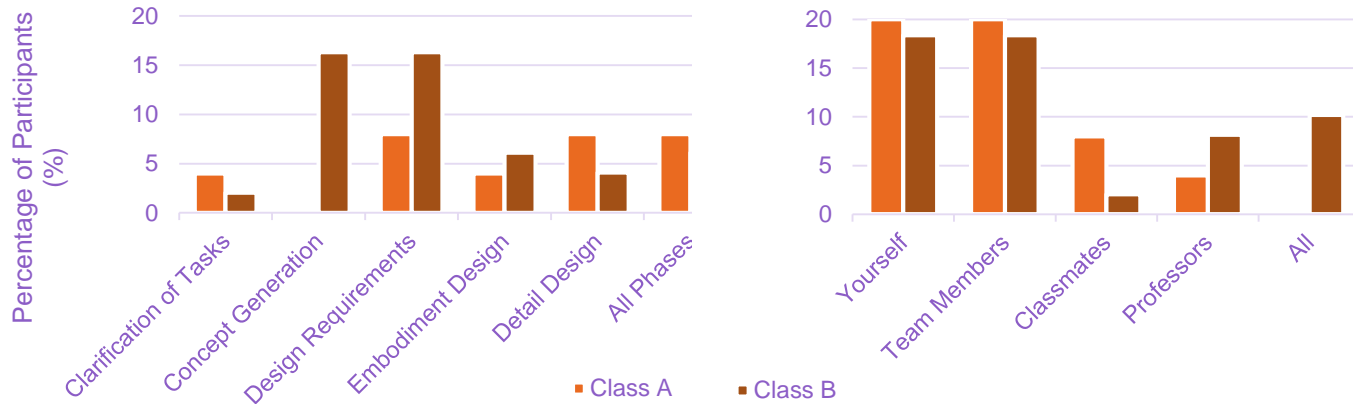


Figure 6. Percent of participants that indicated (left) when DFE were used in the design process and (right) who influenced the use of DFE for Class A and Class B.

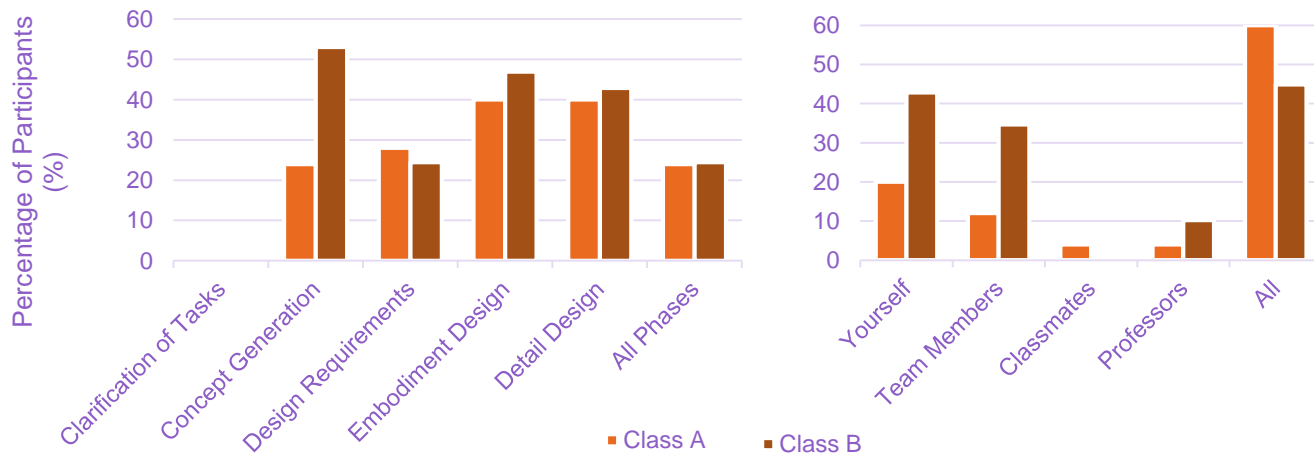


Figure 7. Percent of participants that indicated (left) when DFMA were used in the design process and (right) who influenced the use DFMA for Class A and Class B

- Class A – subject to more DFMA influences
- Class B – subject to more DFE influences
 - Results showed Class A considering more manufacturing aspects and Class B also considered more environmental aspects
- DFMA was considered in all aspects of design except clarification of tasks step in the design process due to the fact that clarification of tasks does not require manufacturability knowledge of the design
- DFE was considered in all aspects in the design process for Class B and all but one for Class A
 - Not considered in the concept generation for Class A but highly contributed in concept generation for Class B
 - This suggests that if DFE is considered, it will be reflected in the early stages of design. This theory was supported by the design review data
- Class B considered manufacturability more than Class A in all aspects except for design requirements suggesting that there may be a link to DFE and DFMA
- Class B considered analogies more than Class A suggesting that DFE has an influence on analogy use
 - Tying environmental aspects into one's design, increases the need for analogies to make these connections
- The use of analogies was also effective in translating the design lesson to the end user

● Potential Issues

- No correlation was found between Class A and Class B effectiveness of design analogies and use due to the teachers not indicating the team that developed their design on the survey.
- There were some flaws in the in design reviews as well as the grade school and student surveys.
 - During the design reviews, students looked to the teacher for feedback. Since students were looking for feedback from the professors, that may have decreased confidence in data being presented, convincing designers to leave out their reasoning for choosing certain design methods and attributes
 - If more reasoning as to why they chose certain materials was discussed, it could have provided more information on whether or not DFE or DFMA was considered

- Trying to identify if what was mentioned in the surveys was actually reciprocated in the survey findings.
- **Next steps:**
 - Assess Product Document Specifications (PDS) Forms
 - Completed weekly
 - Documented criteria, constraints, and requirements for design
 - Changes in DFE/DFMA specs can highlight when actually in the design process or stage the influence was greater
 - Indicate who made the requirement – shows where influence came from
 - Team
 - Sponsor
 - Teacher
 - Show if what was implied from the survey was actually implemented

Questions?

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