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Exploring the relationship between stakeholder identification and divergent thinking on design teams

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ABSTRACT: In this paper, we explore the relationship between divergent thinking and stakeholder identification on 15 student engineering design teams. We examine the relationship between fluency, originality, flexibility, and elaboration on the Alternate Uses Task (AUT), a common measure of divergent thinking, and in stakeholder identification. We find fluency and originality to be positively and statistically significantly correlated between the AUT and stakeholder identification task. Flexibility was positively correlated and elaboration was negatively correlated; both lacked statistical significance. Our results suggest that divergent thinking and stakeholder identification may be correlated, and leveraging exercises to improve divergent thinking may also help improve stakeholder identification. Future work can continue to explore this relationship with larger sample sizes and additional tasks.

KEYWORDS: stakeholder identification, design engineering, user centred design, teamwork

1. Introduction

Engaging in comprehensive and impactful consultation with key stakeholders is of utmost significance in the engineering process (Sharp et al., 1999a). A significant body of research has been undertaken to examine how engineers interact with stakeholders (see, for example, Karlsen, 2008; Mohedas et al., 2020). Nonetheless, the importance of identifying, analyzing, and engaging stakeholders has become a notable area for research within the field of engineering design (Klotz et al., 2018). It is posited that appropriate application of stakeholder analyses can facilitate the framing of issues in a manner that renders them solvable through technically feasible and politically acceptable means, thereby promoting the advancement of the common good (Bryson, 2004). Further, good stakeholder identification and engagement can enhance equity and justice in the engineering design process and can improve the functionality, inclusiveness, and accessibility of the design (Martin et al., 2021; Reed et al., 2009; Vredenburg et al., 2002). The concept of stakeholders has been defined in various ways depending on the field of study. For the purposes of this study, a stakeholder is defined as an individual, a group, or an entity that possesses influence over or is affected by a project or decision.

Numerous studies have demonstrated that the exploration of a broad range of concepts is crucial to the success of engineering projects and their corresponding outcomes (Murphy et al., 2022). While significant, scant research has been conducted on the capacity of engineering teams to delve into a variety of concepts when determining the principal stakeholders pertinent to the challenges they encounter. In this paper, we investigate this matter.

2. Background and motivation

Stakeholder engagement has received ample attention in fields such as business and organizational management (Freeman, 1984), public policy (Bijlsma et al., 2011; Pahl-Wostl, 2002), and resource management (Prell et al., 2009; Reed et al., 2009, 2018), which are often adjacent to the field of engineering design. The implementation of stakeholder identification into the engineering process allows the people and organizations affected by a project to take a central role in influencing design specifications and engineering requirements. By conducting a thorough stakeholder analysis, engineers can prioritize the needs and concerns of these entities and identify potential risks and opportunities (Eschenbach & Eschenbach, 1996). This approach possesses the potential to empower engineering teams to make proactive, informed decisions while balancing social, environmental, and economic objectives in the development of products, services, and processes that are functional, inclusive, and accessible. One area of engineering that has well-established stakeholder engagement methods and approaches is requirements engineering (Pacheco & Garcia, 2012; Sharp et al., 1999b), however, stakeholder engagement within other engineering disciplines, particularly in engineering design, seems to lack clarifications. Research on the development of guidelines in identifying stakeholders has recently started to address this issue (Leventon et al., 2016). Further, the first step of stakeholder engagement, stakeholder identification, is often taken for granted or overlooked, with design teams often carrying over previous stakeholder lists from related design projects. In worst cases, this can lead to the continued marginalization of traditionally overlooked groups in engineering (Reed et al., 2009). Additionally, we have experienced students' resistance to engaging in stakeholder analysis in our engineering design classrooms, where students prefer to jump into concept generation and prototyping rather than taking the time to identify stakeholders and learn about their needs.

Another challenge with stakeholder identification is that it can be challenging to teach. The process of identifying and engaging stakeholders presents considerable pedagogical challenges for educators and students due to the multifaceted criteria required to determine pertinent stakeholders. Moreover, there is a paucity of clear and explicit methodological frameworks in design that facilitate these decisions, particularly within the context of engineering education (Mohedas et al., 2020). In other fields, stakeholder identification is often done by going through a checklist, assembling a group of individuals for a stakeholder brainstorming meeting, or by adopting previous lists of stakeholders from earlier projects (Bryson, 2004). One way to help engineers and designers during the imperative stage of stakeholder identification may be to leverage research on divergent thinking. Divergent thinking is defined as generating many different ideas or concepts in response to a given topic (Guilford, 1957). Since the goal of stakeholder identification is often to identify the most comprehensive list of entities impacted by a project, there is reason to believe that one's ability to identify stakeholders may be linked with one's divergent thinking ability; previous research has shown a similar result in the case of requirement identification (Burnay et al., 2016). If this is the case, researchers and educators in engineering design may be able to draw on the vast literature on divergent thinking to enhance both divergent thinking skills and one's ability to identify stakeholders.

Divergent thinking has received a great deal of attention in fields like psychology, engineering, and organizational behavior as it is generally considered to be a key measure of creativity. One common way of measuring divergent thinking is using Guilford's Alternate Uses Task (AUT) (1967). In the AUT, individuals are given a common object like a brick, a pencil, or a pillow and are asked to generate as many unusual uses for the object as possible (George & Wiley, 2019; Oliva & Storm, 2023). There are several different ways of analyzing responses to the AUT. In this work, we focus on three of the four traditional measures used to evaluate responses on the AUT: fluency, originality, and flexibility. In the AUT, fluency is defined as how many uses a participant developed for a given item; it is measured by counting the total number of distinct uses an individual listed. Originality considers how infrequently a specific use came up. This can be manually coded or can be assessed using measures like semantic distance (Beaty et al., 2022). Flexibility looks at how many different categories of uses an individual listed and is often coded manually. We consider these three measures in the following work. A fourth measure, elaboration, is also often assessed, which looks at the level of detail of an individual's responses; we chose to omit elaboration in this work, as detailed in the methods section. In addition to being able to leverage existing work on divergent thinking if stakeholder identification and divergent thinking are linked, it may also allow for a new method to measure stakeholder identification, which has been challenging to measure. The primary research question for this work is *How is a team's divergent thinking ability and ability to identify stakeholders related?* Our overarching hypothesis is that teams that demonstrate better divergent thinking skills will also do a better job at identifying stakeholders in a design project. Guided by the common concepts within the divergent thinking and alternate uses task literature, we explore more specifically:

RQ 1.1: How is a team's fluency in the AUT and fluency in stakeholder identification related?

- Hypothesis 1.1: We anticipate that a team's fluency in the AUT and fluency in stakeholder identification are positively correlated.

RQ 1.2: How is a team's originality in the AUT and originality in stakeholder identification related?

- Hypothesis 1.2: We anticipate that a team's originality in the AUT and in stakeholder identification are positively correlated.

RQ 1.3: How is a team's flexibility in the AUT and flexibility in stakeholder identification related?

- Hypothesis 1.3: We expect that a team's flexibility in the AUT and in stakeholder identification are positively correlated.

RQ 1.4: How is a team's elaboration in the AUT and elaboration in stakeholder identification related?

- Hypothesis 1.4: We expect that a team's elaboration in the AUT and in stakeholder identification are positively correlated.

3. Methods

The research question we address in this study is how a team's divergent thinking ability and ability to identify stakeholders are related. We examine this question from each of the four concepts used in the Alternative Uses Task: fluency, originality, flexibility, and elaboration. This research was conducted using a within-subjects research design where teams of students completed two tasks: the Alternate Uses Task to measure divergent thinking and a stakeholder identification task based on a design vignette.

3.1. Research context

Participants were students in two different upper-level engineering courses at a public university on the East Coast of the United States. Students were randomly assigned to teams of 4 students, and the research was approved by the University's Institutional Review Board. A total of 60 students from 15 teams participated in this research. Only 56-57 of the participants completed the demographics questions. The average age of students was 23.5 years. The sample was 57.1% female, 41.1% male, and 1.8% non-binary, other, or prefer not to say. Participants were 12.5% Asian, 7.1% Black, 5.4% Latinx, 3.6% Mid-African, 60.7% White, and 10.7% two or more races. 49.1% of participants were undergraduates and 50.9% of participants were graduate students. Participants came from a variety of disciplines, including Aerospace Engineering (1.8%), Architectural History (1.8%), Architecture (22.8%), Biomedical Engineering (5.2%), Civil Engineering (29.7%), Computer Science (1.8%), Engineering Science (1.8%), Landscape Architecture (1.8%), Mechanical Engineering (3.5%), Public Policy (3.5%), and Systems Engineering (26.3%).

3.2. Procedure and data collection

When students arrived at class on the day of the study, they were randomly assigned to teams. Next, participants completed IRB consent documentation. They then completed a survey that included demographics questions. Students then worked with their teams on a set of team activities following a set of written instructions. They began with brief team introductions. The data used in this study was collected as part of a larger study exploring the relationship between team psychological safety and stakeholder identification.

Participants were given a design vignette focused on a proposed trail pavement restoration project. The project description included a written description, photos of the trail, and a map of the relevant area to enhance the realism of the study, and the proposed project description and images were pulled directly from the city's website. Participants were asked to read the design vignette, then *"use 5 minutes to list all of the individuals, groups, and entities who will be AFFECTED by the project. Be as specific as possible."* Teams created written lists of these stakeholders which we later used to evaluate a team's ability to identify stakeholders.

Participants were then asked to complete the Alternate Uses Task (AUT) (Guilford, 1967) to evaluate the team's divergent thinking ability. They were asked specifically *"As a team, please write down as many unusual uses for the following object as possible: brick."* They were also provided with an image of a brick. The AUT is frequently time-limited, with studies using various time limits such as 2 minutes

(Dumas & Strickland, 2018; Wahbeh et al., 2024), 3 minutes (Sahar, 2022), 5 minutes (Erwin et al., 2022); this study allocated a 3 minute time limit to facilitate the progression of participants through the procedure, while avoiding an unnecessary limitation on the quantity of responses.. Upon completion of these two tasks, teams submitted written lists of the stakeholders they identified and of their unusual uses for the brick. This resulted in 15 AUT lists and 15 stakeholder ID lists which were used in our analysis.

3.3. Data analysis

To compare the results from the stakeholder identification task and the results from the AUT, the traditional measures considered in AUT coding were used (Reiter-Palmon et al., 2019). To differentiate the stakeholder identification task from the AUT, the lists of identified stakeholders were evaluated for quality and relevance, and irrelevant or seemingly random stakeholders were removed. Six of 213 total responses were removed, including responses like "safety controls" and "the entire state of Wisconsin," which were not relevant stakeholders. Both the stakeholder identification lists, and the alternate uses task lists were coded for fluency, originality, and flexibility. Fluency was analyzed by counting the number of distinct stakeholders or alternate uses each team identified. Originality was coded manually to assess the statistical infrequency of each listed item. Flexibility was analyzed by assessing the number of conceptual categories within which users or stakeholders could be binned. Flexibility was coded manually using 3 independent coders. Elaboration was analyzed by coding the number of meaningful words per response, then calculating the average number of meaningful words each team used. A Pearson correlation analysis was then conducted between the values for fluency, the values of originality, the values of flexibility, and the values of elaboration on each team.

4. Results

4.1. Fluency

A team's fluency in the AUT and fluency in identifying stakeholders was correlated with a correlation coefficient of r=0.542 and a p-value of 0.037, which suggests that this correlation is statistically significant. This supports our hypothesis that fluency in the AUT and in stakeholder identification would be positively correlated. The number of stakeholders identified ranged from a minimum of 5 to a maximum of 20 with an average of 13.1. The number of alternate uses identified ranged from a minimum of 4 to a maximum of 23 with an average of 16.5. These results are summarized in Tables 1 and 2.

Table 1. Summary of results of correlation between Alternate Uses Task and Stakeholder Identification. Statistically significant P-values < 0.05 are starred

	Pearson's correlation coefficient (r)	p-value
Fluency	0.542	0.037*
Originality	0.655	0.008*
Flexibility	0.475	0.073
Elaboration	-0.131	0.641

4.2. Originality

A team's originality in the AUT and originality in identifying stakeholders was correlated with a correlation coefficient of r=0.655 and a p-value of 0.008, suggesting that this correlation is statistically significant. This supports our hypothesis that originality in the AUT and in stakeholder identification would be positively correlated. Originality scores for stakeholders identified ranged from a minimum of 0.046 to a maximum of 0.096 with an average of 0.064. Originality scores for alternate uses identified ranged from a minimum of 0.010 to a maximum of 0.049 with an average of 0.021. Based on our calculations, lower originality scores mean that the team identified fewer common stakeholders or users and therefore lower scores correspond to higher levels of originality. These results are summarized in Tables 1 and 2.

4.3. Flexibility

A team's flexibility in the AUT and flexibility in identifying stakeholders was correlated with a correlation coefficient of r=0.475 and a p-value of 0.073, suggesting that this correlation is not statistically significant. This does not support our hypothesis that flexibility in the AUT and in stakeholder identification would be positively correlated. The number of categories of stakeholders identified ranged from a minimum of 4 to a maximum of 7 with an average of 5.9. The number of categories of alternate uses identified ranged from a minimum of 2 to a maximum of 10 with an average of 7.5. These results are summarized in Tables 1 and 2.

Table 2. Summary of descriptive statistics for results from fluency, originality, flexibility, and elaboration measures

Measure	Activity	Minimum	Maximum	Mean
Fluency	Stakeholder identification	5	20	13.1
	AUT	4	23	16.5
Originality	Stakeholder identification	0.046	0.096	0.064
	AUT	0.010	0.049	0.021
Flexibility	Stakeholder identification	4	7	5.9
	AUT	2	10	7.5
Elaboration	Stakeholder identification	1.4	2.5	1.86
	AUT	1	2.35	1.7

4.4. Elaboration

A team's elaboration in the AUT and elaboration in identifying stakeholders were negatively correlated with a coefficient of r=−0.131 and a p-value of 0.641, suggesting that this correlation is not statistically significant. The average number of meaningful words used in stakeholder identification ranged from a minimum of 1.4 to a maximum of 2.5 with an average of 1.86. The average number of meaningful words used in the AUT ranged from a minimum of 1 to a maximum of 2.35 with an average of 1.7. These results are summarized in Tables 1 and 2.

5. Discussion

5.1. Findings

The findings showed that fluency and originality between the AUT and stakeholder identification are statistically significant. Considering the limited sample size, this suggests that stakeholder identification was, to some extent, a divergent thinking exercise. While the goal of stakeholder identification certainly aligns with the principles of divergent thinking, it is necessary to identify the relationship between divergent thinking and stakeholder identification, as there is reason to believe that there may be distinct differences between the two. Stakeholder identification, for example, is highly context-dependent, and one's ability to adequately identify stakeholders may require deep context-specific knowledge, which is not always required in divergent thinking. Further, the focus on developing a list of relevant people, rather than inanimate objects, may meaningfully change the activity. To date, there are few empirical studies on this aspect.

Conversely, we found that the correlation between flexibility on the AUT and stakeholder identification was not significant. This did not support our hypothesis, though the inability to detect a statistically significant difference could be due to our limited sample size or the minimal range of possible values for flexibility in these activities. Alternatively, the stakeholder identification task used may not have allowed for a large enough range of categories, which is something to consider in future work. Similarly, the correlation between elaboration on the AUT and stakeholder identification tasks was found to be insignificant. This is possibly due to a combination of the time limit imposed during the tasks; the time limit could incentivize less elaboration in an effort to provide more responses.

These findings suggest that activities that develop divergent thinking could potentially help engineers and designers better identify stakeholders for design projects. Such activities include cognitive mapping (Sun et al., 2019) and mind-mapping (White et al., 2012), far-field analogies (White et al., 2012), and improvisational activities (Felsman et al., 2020; Lewis & Lovatt, 2013; Sowden et al., 2015). These activities have the potential to be incorporated in both the engineering classroom and in professional practice to help improve stakeholder identification. Additionally, these findings suggest that divergent thinking measures such as fluency and originality may be adapted as a way of measuring stakeholder identification. There is not currently a validated set of measures for stakeholder identification, making it challenging to evaluate this step during engineering design. The possibility of adapting existing measures to assess stakeholder identification is promising to advance this area of work.

5.2. Limitations

There are several limitations of this work. First, as the main intent of this study was to pilot the procedures for a larger study, our sample size was limited to 15 teams. Future research can conduct this work with a larger sample size with individual participants and with teams to increase statistical power. Running an a priori correlation analysis in G*Power (Faul et al., 2007, 2009) suggests that a sample size of 134 would be sufficient to detect moderate correlations between items. Another limitation is that we only incorporated one stakeholder identification activity and one item for the alternate use task. Future work may consider incorporating additional stakeholder identification activities in multiple design contexts and additional items in the AUT to enhance internal validity; a minimum of three different cases for each would be a good start.

5.3. Research uncovered and future work

This research suggests several directions for future work. First, to address some of the limitations of this small study, future work should expand on this by incorporating larger sample sizes. Future studies should also incorporate additional items within the AUT and additional vignettes for stakeholder identification tasks. These larger studies could also incorporate additional measures such subjective creativity. It would be helpful to design experiments to investigate whether activities that help build divergent thinking skills also help with stakeholder identification. Studies can also be developed to validate whether AUT measure can be used as stakeholder identification measures, and it would be valuable to further explore potential measures for stakeholder identification. This would expand our ability to evaluate stakeholder identification in engineering design and to identify and disseminate activities that can improve engineers' abilities to identify stakeholders.

6. Conclusion

In this study, we find that fluency and originality between the AUT and a stakeholder identification task are positively correlated. This suggests that activities shown to enhance divergent thinking may also improve designers' abilities to identify stakeholders, which is a critical stage in the engineering design process. We recommend future studies to expand this study to a larger sample with additional AUT and stakeholder identification activities to further evaluate the relationship between these two tasks. Future work can also explicitly evaluate the effectiveness of activities shown to improve divergent thinking on stakeholder identification. Studies can also consider whether measures from the AUT can be adapted to measure stakeholder identification abilities.

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