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Assessing the Development of Empathy and Innovation Attitudes in a Project-based Engineering Design Course

Mr. Antti Oskari Surma-aho, Aalto University

M.Sc. Antti Surma-aho is a doctoral student at Aalto University. He has been conducting research at Aalto Design Factory since January 2017, supervised by Prof. Katja Hölttä-Otto. Antti's academic interests include design thinking, human-centered design, and usability.

Dr. Tua A. Björklund, Aalto University

Tua Björklund is one of the co-founders and the head of research at Aalto University Design Factory. She conducts and leads research, teaches product design, and facilitates pedagogical development at the Design Factory. Tua has a DSc degree in industrial engineering and management and a MA degree in cognitive science.

Prof. Katja Holtta-Otto, Aalto University

Katja is a professor of Product Development and the Aalto University Design Factory, School of Engineering

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Abstract

To develop innovative solutions that fit end-users, engineers must understand the end-users' needs. This user-centered aspect of engineering innovation has been highlighted in recent design thinking literature, where the construct of empathy has received increasing attention. Anecdotal support has been found for the benefits of empathy in engineering, and many engineering design thinking courses today teach engineering students to empathize with end-users. However, transitioning from anecdotal to evidence-based education requires being able to measure and track the knowledge, skills, and attitudes that educators attempt to impart on students. Thus, this study measures the development of empathic tendencies and innovation attitudes in students, and explores correlations between the two.

Data was collected by administering a self-report survey in January and June 2017 to 237 students participating in a global multidisciplinary design thinking course. The survey included subscales for empathic tendencies, innovation self-efficacy, and innovation interests. The responses were analyzed for differences in distribution between the two surveys, as well as for correlations between items. It was observed that the students' empathic tendencies and confidence in experimenting and associative thinking grew ($p < 0.03$). Furthermore, the empathic tendency scores displayed weak but statistically significant correlation with interest towards planning and research activities ($p < 0.05$, $\tau_b > 0.2$). This study is among the first to quantify the development of empathy and innovation attitudes in engineering education. The results indirectly repeat prior research on the development of innovation capabilities in the scope of individual engineering courses. However, there are some limitations regarding the applicability of the utilized survey instruments, thus requiring further research with larger amounts of data and a mixed-methods approach to generalize the results.

Introduction

To remain competitive, today's engineers must be equipped to produce innovative solutions. Thus, engineering educators strive to teach their students the tools and mindsets required for making change. However, despite these efforts, there is conflicting research on whether the innovation capabilities [1] of senior engineering students top those of undergraduate freshmen. For example, in open-ended design ideation tasks, seniors and freshmen were equally innovative when measured cross-sectionally [1], but also showed an increase in innovativeness when it was measured before and after a project course [2] as well as when measured longitudinally for the same group of students [3]. These mixed results indicate that a deeper understanding is needed about the factors influencing the development of innovativeness in engineering students.

Recently, two constructs have received special attention with regards to engineer innovativeness: empathy and self-efficacy, i.e. feeling and understanding the experiences of others and believing in one's own ability to perform tasks. Research suggests that empathy in engineering and design comprises of intrinsic skills, observable actions, and a holistic mindset [4], and can help designers understand and care for end-users [5]. Understanding end-users in engineering may contribute to market success, as a majority of innovative breakthrough products involve novel user interfaces [6]. Further, the established design process guides published by Stanford d.school [7] and IDEO [8] place empathy among the first steps to take when aiming for innovation. As for self-efficacy, it is currently hypothesized that it influences an engineer's interest and ability to carry out tasks associated with innovativeness [9], such as open-minded design exploration [10]. However, despite educators attempting to teach empathy [11], [12] and innovation self-efficacy to engineering students, there is little understanding as to whether students develop either of these mindsets. Thus, formally measuring the development of empathy and innovation self-efficacy in this context would aid educators in better understanding the skills they impart on their students.

Objectives and research questions

The aim of this study is to measure the development of empathic tendencies as well as innovation self-efficacy and interest in graduate-level students during a multidisciplinary project-based design thinking course. This objective can be expressed through the following research question:

- RQ1. Do the empathic tendencies, innovation self-efficacy, and innovation interests of student designers change in a design thinking project course?
- RQ2. Do the students' self-reported empathic tendencies correlate with their innovation self-efficacy and/or interests?

Background

Empathy, perspective taking, and their relevance to design

Empathy, at its most fundamental level, can be considered as one individual's reactions to the observed experiences of another [13]. It is commonly depicted as a dichotomy between affective and cognitive reactions, where an individual might mirror the emotions of the other, generate feelings of their own, and purposefully attempt to make sense of the other's experience and actions [14]. These cognitive attempts to understand what another person is going through are called perspective taking, and can involve the observer imagining either the other's thoughts or their own thoughts as if they were in the other's situation [15]. Many of these activities are mediated by intrinsic and extrinsic motivation, as opposed to the more automatic affective reactions [16]. Skills and motivation in perspective taking may be relevant for human-centered designers, as they are considered beneficial in other human-centered professions, such as psychiatry and medicine [14].

Several methodologies exist for measuring empathy, including self-report surveys, standardized interviews and observation frameworks, as well as physiological measures, including neuroimaging techniques [15]. The most common measuring instruments are self-report surveys

[15], such as the widely utilized Interpersonal Reactivity Index (IRI) [13], which includes a separate subscale for perspective-taking tendencies (IRI:PT).

In engineering and design, empathy is generally considered a technique to holistically understand and connect with the potential end-users of a design [5]. While engineer and design students have been observed utilizing empathic techniques, such as interacting with users and developing user-centered design criteria, throughout the design process [17], there are also indications of them struggling with conflicting comments from different users [18], developing overly simplistic solutions for them [19], and deliberately choosing to prioritize technical aspects over user needs [20]. These problems in understanding and respecting end-users suggest that there is room for improvement in how human-centered design and design thinking are taught.

Furthermore, the development of empathy and perspective taking during engineering and design education has been studied scarcely, and primarily with qualitative methods. For example, in an interview study, Hess et al. [12] found that students' perspective-taking skills develop when they interact with people from different backgrounds and experience challenges in decision making. One of the few quantitative studies found that the empathic tendencies, as measured by IRI, of students grew in a project course [21], albeit with a sample size of only 16 students. Thus, while empathy and perspective taking are well-established concepts and present in human-centered design work, their development in engineering and design education has not been widely measured nor studied.

Self-efficacy and innovation

Bandura's self-efficacy model [10] and the social cognitive career theory [22] have been widely utilized in engineering education research. These models define self-efficacy as an individual's belief in their ability to successfully complete tasks and reach desired outcomes. Further, it is claimed that an individual's perceived self-efficacy towards a specific activity influences their interest towards it, both of which indirectly influence the individual's choice to further practice the activity and gain proficiency at it. This finding was repeated in engineering education by a cross-sectional study on educators and students, where it was found that engineering design self-efficacy was influenced by experience and correlated with task-specific motivation (i.e. interest), among other factors [23]. In other engineering-specific self-efficacy research, a longitudinal study of a multi-disciplinary undergraduate project course observed an increase in students' self-efficacy for cross-disciplinary learning, suggesting that such teaching interventions can help students learn collaboration [24].

Recently, engineering students' self-efficacy for innovation activities has sparked interest in academic research. Based on the key innovation activities defined by Dyer et al. [25] (i.e., questioning, observing, experimenting, associating, and networking), Gilmartin et al. [9] developed the Engineering Majors Survey and its various subscales to quantify the innovative tendencies of undergraduate US engineering students. The Engineering Majors Survey includes scales for measuring Innovation Self-Efficacy (ISE), Innovation Interests (INI), and several others, such as engineering outcomes and career interests. Initial results suggest good internal and external validity, correlation between certain ISE and INI items [26], as well as that extra-curricular and multi-disciplinary activities influence ISE scores [27]. However, little research on innovation self-efficacy and interests has been conducted outside US undergraduate students and cross-sectional settings.

Research Method

In this study we measure the development of empathy and innovation attitudes by administering a self-report survey to the students of a graduate-level design thinking project course twice, first early in the project and again at its end. The course involved students from various universities around the globe solving open-ended problems for industry liaisons.

Participants

This study was carried out in the context of a project-based graduate-level course called ME310 Global Innovation Program during spring 2017. The course lasts for one academic year, and in the year 2016-2017 it included 237 students in 16 universities [28]. The course work is centered around open-ended industry projects that the students tackle in multidisciplinary teams, and is accompanied by formal teaching of the Stanford Design Thinking process and its associated human-centered tools and mindsets. The exact teaching methods employed vary between universities, but tend to involve not only lectures but also workshops, team-specific mentoring, peer reviews, and design review sessions. However, there are no specific teaching interventions for empathy (such as those described by Walther et al. [11]) nor self-efficacy within the course curriculum.

Survey measures

We administered a self-report survey to the students of ME310 Global Innovation Program twice during the course in 2017: first in January and again in June. The one-page, 25-item survey comprised three distinct Likert-type subscales: IRI:PT measuring empathic perspective-taking tendencies (7 items), as well as ISE (6 items) and INI (5 items) measuring innovation self-efficacy and interests. Additionally, students were asked to specify their project team, name, age, sex, major, and nationality (6 items). The survey also included one item assessing leadership self-efficacy, which was not included in this study. Empathy was not mentioned in the survey directly at any point and the items of the three scales were mixed in presentation order to avoid attracting participant attention to the measurements. The complete survey can be found in Appendix I.

The specific survey scales were chosen based on existing research. The IRI:PT scale was included due to its frequent use in quantifying empathy in specific populations and assessing changes over time [29] as well as existing comparison data for engineering students [21], [30]. The ISE and INI scales from the Engineering Majors Survey [9] were included primarily due to their clear focus on established innovation mindsets and engineering education, as well as the existence of extensive baseline data [26]. In order to keep the length of the survey instrument reasonable, several potentially useful scales were left outside the scope of this study.

The survey was administered in differing manners in January and June. In January, printed surveys were handed to students during a course event where a majority of the participating students were gathered. In June, printed surveys were administered at events in various locations, and a link to a digital survey was sent to course staff in various participating universities with a request to forward it to students. In all cases, the surveys were distributed and collected by the authors, and afterwards their contents were digitalized and anonymized for analysis.

Data analysis

Responses were excluded if a respondent had all their answers in a single column (i.e. “moderately agree” on every question), and if any scale was missing more than one answer. Only one response was excluded as a result of this procedure. If respondents had checked multiple choices for one question, the average of their answers was calculated. Similarly, if a respondent had drawn a mark between two choices, the average was used as their response. All missing data points were left blank and analysis performed on the remaining responses.

All descriptive statistics were calculated for four distinct datasets: paired January responses, paired June responses, all January responses, and all June responses. The internal reliabilities of the IRI:PT, ISE, and INI scales in each of the four datasets were assessed with Cronbach’s alpha (α) and item-total correlation (r), with limits set at $\alpha > 0.7$ for the scale (defined “acceptable” [31]) and $r > 0.3$ for all its items (suggested cutoff [32]). Furthermore, all subscales were individually subjected to factor analysis to ensure their unidimensionality. In addition, other types of validity were assessed by observing the impact of sex on IRI:PT scores and searching for correlations between similarly worded ISE and INI items. It was expected that IRI:PT scores are higher for women [13], [30], [33] and that the ISE and INI questions centered around similar innovation characteristics would show some degree of correlation [26].

After the validity assessments, changes in the distribution of January and June responses for each survey scale were evaluated with Wilcoxon signed-rank tests for the paired dataset and Mann-Whitey U tests for the full dataset, when applicable. We justified using the full dataset by comparing the distributions of paired and unpaired responses for each survey scale in both January and June responses were with Mann-Whitney U tests. The center point and spread of the survey scores are reported with mean and standard deviation, respectfully. Lastly, correlations between survey scales and items were sought nonparametrically with Kendall’s tau-b (τ_b).

Results

Table 1 presents the descriptive statistics of the January and June survey responses as well as the respondents who answered both surveys. The number of paired responses ($N = 41$) was noticeably lower than the full number of responses in both surveys ($N_{Jan} = 168$, $N_{Jun} = 61$), justifying attempts to analyze the full dataset. Overall, the datasets were similar in the distribution of majors and sexes, with each dataset including students from more than 10 different universities and nationalities.

Table 2 shows the Cronbach's alpha scores for all survey scales, as well as the factor loadings of individual items. Alpha scores were below the threshold of 0.7 for all survey scales except for IRI:PT in the June survey. This indicates that there was a degree of randomness in the students' responses [31]. Further, none of the subscales were unidimensional based on principal component factor analysis with varimax rotation. While most alpha coefficients were above 0.6, the INI scale alpha in both January datasets was roughly 0.4, suggesting that the students answered INI questions at random in the beginning of the project. It can be observed that the June datasets had a higher alpha than their January counterparts, in all cases except paired ISE responses.

Table 1. Descriptive statistics for all the analyzed survey datasets.

	All January			All June			Paired		
	N	%	Valid %	N	%	Valid %	N	%	Valid %
Responses	168	70.9	100.0	61	25.7	100.0	41	17.3	100.0
Missing	69	29.1		176	74.3		196	82.7	
Nationality									
Reported	116	69.0	100.0	25	41.0	100.0	22	53.7	100.0
Missing	52	31.0		36	59.0		19	46.3	
Sex									
Male	98	58.3	59.8	26	42.6	55.3	23	56.1	56.1
Female	66	39.3	40.2	21	34.4	44.7	18	43.9	43.9
Missing	4	2.4		14	23.0		0	0.0	
Major									
Engineering	78	46.4	48.4	24	39.3	54.5	23	56.1	56.1
Design	35	20.8	21.7	11	18.0	25.0	11	26.8	26.8
Business	29	17.3	18.0	5	8.2	11.4	4	9.8	9.8
Other	19	11.3	11.8	4	6.6	9.1	3	7.3	7.3
Missing	7	4.2		17	27.9		0	0.0	

Based on the sub-par internal reliability, modifications to the survey scales were explored. Despite exploring whether singular items could be deleted from each scale, no suitable solutions were found for increasing the alpha coefficient above 0.7 in all four survey datasets (as seen in Table 2). For the Perspective Taking scale of the Interpersonal Reactivity Index (IRI:PT), a recently developed brief version of the instrument, B-IRI:PT [33], yielded alpha coefficients higher than 0.7 for all datasets (0.702 to 0.827), and a factor analysis further confirmed its unidimensionality. The B-IRI:PT comprises four questions, IRI-08, IRI-11, IRI-25, and IRI-28. Thus, IRI:PT scores were computed based on four items, whereas ISE and INI scales were analyzed at the level of individual items.

Next, the B-IRI:PT as well as the individual ISE and INI items were analyzed for differences in distribution between the paired and unpaired responses in the January and June datasets. No statistically significant differences were observed between the distributions of responses (p >

0.05). However, the differences in responses to items ISE-2, ISE-5, ISE-6, and INI-3 approached statistical significance with p values below 0.1. Thus, in further analysis, it was decided to consider only paired responses for these specific items. For other items as well as the B-IRI:PT results, analysis is presented for both the paired and full datasets.

Table 2. Internal validity scores for the paired and full survey datasets in both January and June. Values are bolded when they indicate that a question could be removed. The original content of the survey can be found in Appendix I.

	Paired				All			
	January		June		January		June	
	Alpha loading	Corrected item-total correlation	Alpha loading	Corrected item-total correlation	Alpha loading	Corrected item-total correlation	Alpha loading	Corrected item-total correlation
IRI-03 (-)	**0.700**	**0.262**	0.806	0.437	**0.698**	**0.199**	0.765	0.398
IRI-08	0.653	0.446	0.777	0.604	0.639	0.411	0.730	0.564
IRI-11	0.624	0.543	0.744	0.788	0.626	0.454	0.713	0.660
IRI-15 (-)	0.656	0.433	**0.816**	0.388	0.678	**0.271**	0.772	0.358
IRI-21	**0.718**	**0.159**	0.800	0.464	0.654	0.351	0.762	0.401
IRI-25	0.602	0.645	0.786	0.547	0.596	0.559	0.736	0.533
IRI-28	0.668	0.387	0.768	0.647	0.607	0.513	0.726	0.579
α	*0.696*		*0.811*		*0.679*		*0.772*	
ISE-1	0.556	0.571	0.554	0.472	0.592	**0.280**	0.631	0.465
ISE-2	0.571	0.542	0.556	0.469	0.520	0.448	0.602	0.539
ISE-3	**0.677**	**0.232**	**0.664**	**0.163**	0.571	0.313	0.685	**0.287**
ISE-4	0.609	0.464	0.562	0.487	0.517	0.461	0.625	0.500
ISE-5	**0.699**	**0.210**	0.610	0.346	0.599	**0.272**	0.668	0.377
ISE-6	0.619	0.420	0.617	0.316	0.567	0.326	0.664	0.367
α	*0.668*		*0.640*		*0.605*		*0.688*	
INI-1	0.372	**0.216**	**0.697**	**0.227**	0.356	**0.174**	**0.642**	**0.217**
INI-2	**0.462**	**0.139**	0.517	0.633	**0.400**	**0.133**	0.522	0.482
INI-3	0.305	0.326	0.601	0.509	0.253	**0.299**	0.569	0.406
INI-4	**0.446**	**0.107**	0.641	0.416	0.377	**0.149**	0.565	0.411
INI-5	0.239	0.378	0.638	0.408	0.296	**0.250**	0.560	0.416
α	*0.420*		*0.678*		*0.390*		*0.630*	

Table 3, Table 4, and Table 5 present the changes in B-IRI:PT scores as well as ISE and INI items between the January and June surveys, and specifies their statistical significance. The B-IRI:PT scores display statistically significant growth in both datasets, indicating that the students' self-rated capability to consider the perspectives of others increased in the project course. Also, female students had slightly higher B-IRI:PT scores than males ($p < 0.03$ for all datasets).

In ISE, items 3, 4, and 6 displayed statistically significant growth, indicating that students felt more capable in connecting concepts and ideas into new wholes as well as experimenting to find innovative ideas and understand how things work. ISE-1 showed statistically significant growth only in the paired dataset, thus tenuously indicating that students felt more able to ask a multitude of questions in their design work. The average scores for the whole scale also showed statistically significant growth ($p < 0.001$), which due to the low Cronbach's alpha should be considered anecdotal. However, a similar growing trend can be observed in all individual items as well.

Table 3. Change in B-IRI:PT score distributions between January and June surveys. Significant changes are bolded.

	January				June				Change	
	α	N	x̅	σ	α	N	x̅	σ	Δ	p
B-IRI:PT (Paired)	.744	41	3.59	.73	.827	41	3.79	.77	.20	**.028[a]**
B-IRI:PT (All)	.702	168	3.54	.68	.778	61	3.80	.70	.26	**.022[b]**

Table 4. Changes in ISE item score distributions between January and June surveys. Significant changes are bolded.

	January			June			Change	
	N	x̅	σ	N	x̅	σ	Δ	p
ISE-1: Questioning (Paired)	41	3.12	1.00	41	3.54	.95	.41	**.006[a]**
ISE-1: Questioning (All)	167	3.35	1.09	61	3.59	.88	.24	.126[b]
ISE-2: Observing (Paired)	41	3.59	.89	40	3.79	.94	.20	.118[a]
ISE-3: Experimenting (Paired)	41	3.78	.82	41	4.16	.76	.38	**.029[a]**
ISE-3: Experimenting (All)	167	3.77	.84	61	4.12	.76	.35	**.005[b]**
ISE-4: Experimenting (Paired)	41	3.49	.71	41	4.00	.71	.51	**.002[a]**
ISE-4: Experimenting (All)	168	3.63	.81	61	3.93	.73	.30	**.007[b]**
ISE-5: Networking (Paired)	40	3.28	.99	41	3.49	.98	.21	.142[a]
ISE-6: Associating (Paired)	40	3.38	.81	41	3.83	.70	.45	**.001[a]**

Table 5. Changes in INI item score distributions between January and June surveys. Significant changes are bolded.

	January			June			Change	
	N	x̅	σ	N	x̅	σ	Δ	p
INI-1: Experimenting (Paired)	41	4.15	.69	41	4.41	.59	.27	**.033[a]**
INI-1: Experimenting (All)	168	4.23	.72	61	4.41	.56	.18	.132[b]
INI-2: Pitching (Paired)	41	3.15	1.20	41	3.23	1.13	.09	.569[a]
INI-2: Pitching (All)	168	3.26	1.08	61	3.39	1.08	.13	.385[b]
INI-3: Resourcing (Paired)	41	4.17	.70	41	3.89	.79	-.28	.061[a]
INI-4: Planning (Paired)	41	3.68	.91	41	3.62	1.09	-.06	.842[a]
INI-4: Planning (All)	167	3.55	.98	61	3.75	1.03	.19	.146[b]
INI-5: Researching (Paired)	41	3.80	.87	40	3.75	.93	-.05	.554[a]
INI-5: Researching (All)	167	3.74	.89	59	3.80	.94	.06	.588[b]

[a] Wilcoxon signed-rank test.
[b] Mann-Whitney U test

As for INI, no item displayed unanimous statistically significant change. Only the change in INI-1 in the paired dataset was statistically significant, tenuously suggesting that students may have grown more interested in experimentation during the project course. The direction and magnitude of change appear to vary between items, thus revealing no clear trends.

Several correlations were observed between the survey scales. Significant correlations ($p < 0.05$, $\tau_b > 0.3$) were found in all datasets between INI-1 and ISE items 2 and 4, as well as INI-2 and ISE-5. In the first group, all three items deal with ideation (interest in ideating, ideas through observation, ideas through experimentation), while in the second group both items refer to external communication (elevator pitching, building a network of contacts). Also, despite the low Cronbach's alpha scores, average ISE and INI scores showed statistically significant correlation in the paired June dataset, thus anecdotally repeating the results of Schar et al. [26]. For B-IRI:PT, weak correlations at $p < 0.05$ and $\tau_b > 0.2$ were observed with INI items 4 and 5, focused on planning and researching. However, these correlations were not observed in the paired June dataset. No correlations were present between B-IRI:PT scores and ISE items.

Discussion

With the rise of curricula aiming for the development of empathy within design thinking in engineering design education, we need to move beyond anecdotal evidence on how empathy can be cultivated and how it connects to innovative work. In this study, we take a first step towards this aim through measuring the development of empathic perspective taking, innovation self-efficacy, and innovation interests – during a graduate-level design thinking project course. We administered a self-report survey consisting of the IRI:PT, ISE, and INI subscales to the students in the ME310 Global Innovation Program early in the course and at its end, in January and in June.

Analysis of the survey responses indicates that the students' perspective-taking tendencies increased, their self-efficacy in certain innovation activities increased, and that their interest in innovation didn't significantly change. In the perspective-taking scores, the direction and approximate magnitude of change compares well to that found by Hess [21] in a similar context. Further, female students scored slightly higher than males, which repeats the results of other studies involving the IRI instrument [13], [34]. As for self-efficacy, there was an increase in the students' self-efficacy both in connecting seemingly-distant concepts together and in experimenting to find and understand new ideas. These results agree with previously observed increases in student innovativeness in the context of single courses [2]. Lastly, no statistically significant developments were found in the students' interest towards innovation activities. Nevertheless, growth in the Cronbach's alpha score of the INI subscale indicates that the students may have been able to more consistently assess their interest at the end of the course than at the beginning. Overall, these results specify traits that students developed in the project course, thus extending the current understanding of engineering student learning during project-based education.

Furthermore, statistically significant but effectively weak correlations were observed between the students' perspective-taking tendencies and their interest in developing plans and schedules as well as researching phenomena to produce new knowledge. This finding suggests that a relationship may exist between a designer's empathy and their professional interests, which aligns with broader notions of motivation influencing empathy [16], [20].

Limitations

The main limitations of this study are the lacking internal consistency of the administered survey scales and the utilization of self-report-only methodology. In addition, the sample size was low in comparison to other studies relying solely on self-report measures [9], [13].

The internal consistency of the survey scales distributed in this study was below the threshold recommended in literature [31], resulting in the removal of survey items and the analysis of individual questions instead of computing mean scores. The reasons for low internal consistency can only be speculated. For one, the ME310 Global Innovation Program is a multinational course that includes primarily non-native English speakers with varying proficiency levels of English, thus creating a risk of misunderstandings and -interpretations while answering the survey. Supporting this explanation, existing research has shown that the IRI instrument can suffer from poor internal consistency when administered to respondents not fluent in English [33], [35]. Similarly, the ISE and INI scales have been developed for US undergraduate engineering students [9], [26], whereas the respondents in this study represented over ten nationalities.

Another possible reason for the low internal consistency is that the contexts of the IRI:PT scale items were not clear enough for students engaged in and primed towards design and innovation activities, thus resulting in various interpretations. While the IRI was designed for measuring "everyday" empathy [13], the items in the context of a design project course could refer to teamwork, communication with the liaison and the school, or direct contact with end-users. For example, in the item "I sometimes find it difficult to see things from the 'other guy's' point of view", the response might change depending on whether the student imagines "the other guy" as their teammate, liaison, mentor, or end-user. This example illustrates the potential difficulty of using scales with general language in a context-specific situation.

The low internal consistency resulted in the use of a brief version of the IRI:PT scale. With this version, however, the change in scores was observed in both the paired and full datasets, with the instrument having a unidimensional factor structure and an acceptable Cronbach's alpha. Brief versions of IRI have also been used in prior academic research [21], [33], [35]. In a similar vein, the ISE and INI results were analyzed unconventionally item-by-item, but the semantically similar items showed correlation between the two instruments, thus in part enhancing validity.

The second limitation was using exclusively self-report methodology. Self-report surveys may impart a degree of social desirability bias, thus not accurately depicting the true tendencies of respondents. It has been suggested that self-report surveys are best used in combination with other methodology, especially when measuring empathy [15], [29]. It can further be hypothesized that self-report surveys do not capture the full extent of empathy in engineering, as it consists not only of mindsets but also activities and processes [4]. Thus, future research should methodologically not only attempt to address the challenges in applying the IRI, ISE, and INI instruments outside their designed context, but also triangulate the measurements with, for example, observational and other qualitative methods. Such data was collected by the authors, but its presentation and analysis is left for subsequent papers.

Conclusions

Empathy as well as innovation-related self-efficacy and interests are believed to help engineers create solutions that better match the needs of their end-users, whether they were designing in the context of a larger firm or a startup. However, research on the effect of engineering education on the development of empathy is virtually nonexistent, and even studies linking empathy to innovation outcomes are rare. This study takes a first step towards evidence-based practice by demonstrating that graduate students' self-reported empathy (as measured by perspective taking tendencies) as well as their innovation self-efficacy (as measured by confidence in design-related experimenting and association) increased significantly during a project-based design thinking course. No statistically significant changes were observed in the students' innovation interests. Furthermore, weak but statistically significant correlations were found between perspective-taking scores and the students' interests both in planning the implementation of ideas and in researching phenomena to create new knowledge, linking elements within empathy to interest in certain components of innovative work. This study is among the first of its kind in quantifying the development of empathy and innovation attitudes in engineering education, and as such extends the current understanding of skills students develop in project-based courses. Further research is needed to verify and generalize the results of this study as well as to better understand the activities and teaching interventions that influenced the students' development. Also, future research should explore more diverse methodologies, beyond self-report instruments, for measuring empathy in engineering. Such studies will help us build a more robust foundation for educating engineers equipped for advancing innovations in organizations.

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Appendix I: Survey – Perspectives and exploration in design projects

(Open fields)

1. Team
2. Name

(Disclaimer regarding the above fields)
This is asked only to link your pre- and post- course answers, data will be anonymized for analysis and reporting.

(Instructions)
Please read the statements below and indicate to which degree the statement applies to you. Try to be as honest as possible. Your responses will be anonymized and shared with the teaching team only after the course has ended.

(5-point Likert items, 1 = not true / does not describe me, 5 = describes me extremely well)

3. I am confident in my ability to connect concepts and ideas that appear, at first glance, to be unconnected *(ISE-6)*
4. I'm interested in experimenting in order to find new ideas *(INI-1)*
5. Before criticizing somebody, I try to imagine how I would feel if I were in their place *(IRI-28, PT)*
6. I am confident in my ability to ask a lot of questions *(ISE-1)*
7. I'm interested in giving an "elevator pitch" or presentation to a panel of judges about a new product or business idea *(INI-2)*
8. If I'm sure I'm right about something, I don't waste much time listening to other people's arguments *(IRI-15, PT)*
9. I am confident in my ability to generate new ideas by observing the world *(ISE-2)*
10. I sometimes try to understand my friends better by imagining how things look from their perspective *(IRI-11, PT)*
11. I'm interested in finding resources to bring new ideas to life *(INI-3)*
12. I believe that there are two sides to every question and try to look at them both *(IRI-21, PT)*
13. I am confident in my ability to experiment as a way to understand how things work *(ISE-3)*
14. I'm interested in developing plans and schedules to implement new ideas *(INI-4)*
15. I sometimes find it difficult to see things from the "other guy's" point of view *(IRI-3, PT)*
16. I am confident in my ability to actively search for new ideas through experimenting *(ISE-4)*
17. I try to look at everybody's side of a disagreement before I make a decision *(IRI-8, PT)*
18. I'm interested in conducting research on phenomena in order to create new knowledge *(INI-5)*

19. I am confident in my ability to build a large network of contacts with whom you can interact to get ideas for new products or services *(ISE-5)*
20. When I'm upset at someone, I usually try to "put myself in his or her shoes" for a while *(IRI-25, PT)*
21. I am confident in my ability to lead a team of people *(Leadership)*

(Open fields)

22. Age
23. Sex
24. Major
25. Nationality