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Role of Relevance in Professional Skills Application in Undergraduate Multi-Disciplinary Teams

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Introduction and Background

The updated accreditation criteria set by ABET includes student learning outcomes that put emphasis on development of professional skills for nurturing practicing engineers in today's society. Studies suggest that there exists a gap between recent graduates and industry expectations on this front [1][2][3]. These studies suggest that recent graduates have lack of experience in project work, problem solving abilities and communication skills relevant for the industry. Many efforts and strategies are being deployed towards addressing this gap in the university settings including industry collaborations [4][8], personalized curriculums focusing on integration of theory and practice [6], experiential, project based learning and multi-disciplinary approach [7][8] are being actively integrated into educational programs and are being supported with associated success in improving employment-based skills for undergraduate students.

One such example of these efforts is the Vertically Integrated Projects (VIP) Program at Purdue University, which provides opportunities for undergraduate students to earn academic credit by participating in real-world research and design projects aligned with active research areas of Purdue faculty members and national, international, and industry-sponsored design challenges. VIP teams are multi-disciplinary and vertically-integrated (first-year through seniors) with faculty and graduate student mentors and extend over multiple semesters or years. Because the projects and teams within this program span a wide variety of contexts and require very diverse knowledge and skill development, the project work is supplemented with Professional Development (PD) workshops. The PD workshops are short modules ranging over a variety of professional topics that complement traditional curriculum and are intended to provide opportunities for students to learn skills needed for their projects and their overall professional goals.

As part of program evaluation, we seek to study in what ways students participating in these workshops are connecting the skills and concepts taught in these workshops to their academic, professional or personal goals, more broadly, and their projects, more specifically. In addition, this study explores the factors affecting this process. To aid this evaluation, we use data collected from PD workshops, in the form of pre- and post-workshop surveys. This study explores the relation between their self-reported intention and confidence to apply these skills and post workshop outcomes and pre workshop conditions. Post workshop outcomes include factors such as change in perception of relevance, role of the workshop, identification of areas of application and valuable lessons, while pre-existing conditions include factors such as self-reported physiological and psychological state of the students.

This paper presents statistical analyses of paired data, collected over 89 unique participants across 9 different topic workshops and the insights that we gained along the aforementioned directions from the pre and post-workshop conditions and outcomes. We see that overall students do want to make connections in what they learn and their other goals. They are successful in identifying applications in many aspects of their lives including professional, research, academic and personal goals. Our analysis found that there is a significant role of the type of the workshop and workshop's ability in teaching and making the topic relevant. In addition, we found the process is also impacted by a student's prior importance and relevance of the topic and their ability to identify valuable concepts at varying depths. Research [9] suggests that transfer of learning can occur when an intent of connection finding, or application is displayed by students. As proposed in [10], individuals when interested will engage in meaning and deeper learning and interest can be developed through many phases including triggered and maintained situational interest in phase one and two of the proposed framework typically supported by external help in finding connections, learning the conceptual framework through instructions and group work.

With this study, we echo the role of both a student's intent in finding connections and external aid in teaching the application of the content. The multidisciplinary nature of the projects, the students are engaged in as part of their coursework and the nature of teams themselves consisting of students coming from 30 different majors necessitates for a better understanding of how to support the overall professional development of such a heterogenous group. The study is a first step in the direction to help better understand the needs and indicated helpful aspects of these workshops that aid the effort of making these students more confident in their skills and their ability to use them elsewhere.

Methods

Study Overview

As part of this study, undergraduate students who participated in Professional Development workshops in VIP at Purdue University were surveyed to understand the factors impacting the adoption and application of skills they learned. As part of this study, we asked three primary research questions:

R1: Are students attending Professional Development workshops able to make connections between skills taught in these sections and their professional, academic or personal goals?
R2: In what ways are they making these connections?
R3: What are the factors affecting this connection making process?

VIP Program

The data for this study was collected from students in the VIP Program at Purdue University in the Spring 2023 semester, during which 487 students from 27 majors were enrolled across over 45 teams. As mentioned previously, the Professional Development workshops are offered to VIP students at Purdue as additional resources for student's development on various fronts. These workshops are short modules ranging between 60-120 minutes which are conducted throughout the semester. The workshops are voluntary participation but can be used to attain partial credit towards the course requirements. Given the nature of projects and teams being multi-disciplinary, the topics of the workshops are chosen carefully taking into account the broader context of undergraduate students, identifying various aspects of their growth. These include topics related to the area of research and design projects and required skills to succeed in them, general communication and professional skill development. In total, 21 workshops on different topics were offered during the course of the semester. The nine topics included in the data used for this study are the following: Persuasion Skills, Data Management with Python, Presentation Skills, Mathematical Optimization, Abstract Writing, Mobile Application Development, No Code Application Development, Deep Learning Tutorial and Agile Project Management. The nine workshops chosen for the data analysis was an outcome of identifying unique participants with a complete survey response. The workshops were conducted by graduate students training in respective fields of research and instructors. The workshops were developed with the focus of providing a hands-on learning experience which included a review of the topic and an applied activity to follow along with the workshop provider.

Participants

The workshops were open to undergraduate engineering students who are enrolled in the above-mentioned program for credit. The students could choose from the many topics offered across the semester and attend as many workshops as they wanted throughout the semester. In total 89 students were selected to be included in the data analysis for this study. These participants were selected in order to identify unique participants spanning across all the workshops who had a 100% response rate in the survey. If a student attended multiple workshops with completed surveys, one entry per student was randomly selected.

Survey Design

As part of attending the workshop, the students were asked to participate in two surveys, one at the start of the workshop and one at the end of the workshop. The surveys were provided to students via a Qualtrics displayed to students. These surveys were optional for the students. The analysis of this survey data was performed as part of a study approved by the Institutional Review Board (IRB) at Purdue University.

In order to aid answering the three research questions listed above, the survey was divided into two parts, pre and post. The following section details the data collection protocol utilized for each respective question.

R1: Are students attending Professional Development workshops able to make connections of skills taught in these sections to their professional, academic or personal goals?

We collected responses from students to the following questions for answering this question:

Outcome	Survey Question	Response
Intent of Application	Q: Are you going to apply what you learnt today elsewhere?	- Yes - Yes I'd like to but I am not confident how to - No
Confidence in Application	Q: How confident are you in being able to apply today's concepts elsewhere?	5-Point Likert Scale: Extremely under confident to Extremely confident

Table 1: Survey questions for collecting data on our outcomes of interest for R1.

R2: In what ways are they making these connections?

We ask students more open-ended questions to assess what kinds of connections these students are making from these workshops as listed below:

Outcome	Survey Question	Response type
Application Type	Q: List two places you see today's content being applicable.	Open-ended
Valuable Concepts Identification	Q: Summarize the key concepts you found most valuable today.	Open-ended

Table 2: Survey questions for collecting data on our outcomes of interest for R2.

R3: What are the factors affecting this connection making process ?

We have identified two kinds of factors that we explore to understand the role of these factors in students making connections and their level of confidence. We divided these factors into pre and post factors. Pre factors are factors like participant's psychological, physiological states and environmental factors at the time of attending these workshops. The post factors are focused more around the workshop related factors like the role of workshop in teaching the concept, the

role of workshop in changing the relevance of these skills for participants, etc. Table 1. summarizes the factors and the questions used to gather data on these factors.

Factors	Description	Questions	Response Type
Physiological	Physical Load	- Are you feeling hungry? - Are you feeling tired/sleepy? - How are you feeling today?	Ordinal on a 3-point Likert scale (3: high)
	Cognitive Load	- How many classes/meetings did you have today before this workshop? - Do you have any academic deadlines today/this week?	Ordinal on a 3-point Likert scale (3-highest)
Psychological	Prior Motivation	- Why are you attending this workshop? - Would you attend a workshop on this topic if it wasn't required for your coursework?	Ordinal on a 3-point Likert scale (3-highest)
	Prior Relevance	Do you think today's topic is relevant to your other academic/professional goals?	Ordinal on a 3-point Likert scale (3-highest)
	Prior Knowledge	How would you rate your current knowledge on this topic?	Ordinal on a 5-point Likert scale (5-highest)
	Prior Importance	Do you think today's topic is important for you?	Ordinal on a 3-point Likert scale (3-highest)
Environmental	Language Proficiency	Do you identify English as your first language?	- Yes - No, but I am proficient in the language. - No
	Education system familiarity	Where did you complete your high school education?	- US - Outside US in an international school - Outside US
Workshop Related Factors Role of workshop in…	Teaching the topic	Was today's workshop helpful in learning the topic?	Ordinal on a 3-point Likert scale (3-highest)
	Teaching the application of the topic	Did the activity help in learning how to apply the concept?	Ordinal on a 3-point Likert scale (3-highest)
	Changing the relevance of the	Is there a change in your thinking after the workshop about the	Ordinal on a 5-point Likert scale(5-highest)

	topic.	relevance of today's content in your other academic/professional goals/projects?	

Table 3: Survey questions for collecting data on relevant factors for R3.

Data Analysis

For analyzing the survey responses, the responses are encoded in the following ways:

For questions which had Yes/Maybe/No kind of responses with a natural order, we have encoded them as ordinal variables with mapping 3/2/1 in that respective order such that the higher value of the variable indicates higher presence of the variable using a Likert scale [16]. Below is an example of a question and its encoding:

Q: Do you think today's topic is important for you?
A: Yes | Not sure but I am curious | No
These answers were encoded as 3|2|1 such that 3 represents affirmative responses and 1 represents negative responses to the question of interest.

For factors where multiple questions were asked, each question response was individually encoded as described above and then an average was taken of the three responses to represent the aggregate response for the factor. For example, In order to assess Physical Load, below three questions were asked:

Questions	Responses	Encoding
Are you feeling hungry?	Yes	No but I might in next 30 minutes	No	3| 2| 1
Are you feeling tired/sleepy?	Yes	A little	No	3| 2| 1
How are you feeling today?	Tired and finding it hard to focus	Not so well but I can focus	Great and active	3| 2| 1

Table 4: Survey data encoding for ordinal variables.

Then an average was taken across all three responses to get an aggregate measure of physical load. For variables where the answers could have been treated as nominal and ordinal, we treated them as both as two independent variables to eliminate any effects of encoding.

For analyzing the data, we used methods like descriptive statistics, correlation analysis, group difference and regression analysis with details and results in the following section.

Results

Exploratory and Descriptive Analysis

We observed that 88.7% participants indicated an overall positive intent of application with 55.1% participants indicated that they would apply the skills learned in their workshops outside the workshops and 33.7% participants indicated the wish to apply these skills elsewhere but lacking confidence. Overall, 82% of the participants indicated somewhat and extreme confidence in the ability to apply the skills outside the workshop (Fig 1).
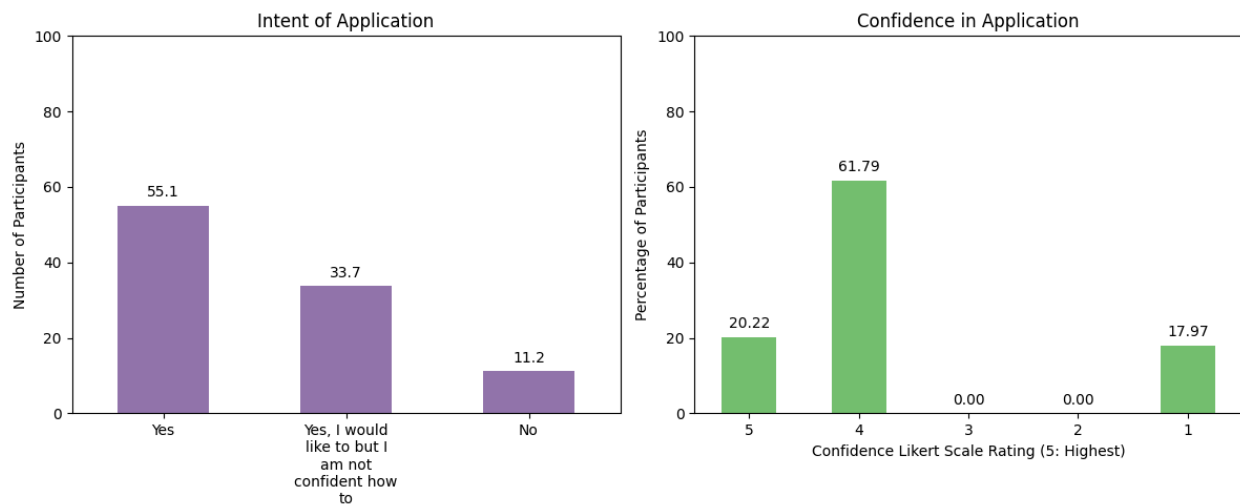

Fig 1. Application Intent and Confidence of workshop topics

When asked further to describe things that would help in getting better confidence, two major themes appeared in the responses: Practice and Time. Most participants indicated the need for practice and time by themselves to absorb the content. There were additional mentions of needing further professional settings and real-world examples of the use of the skills taught in these workshops. A few examples: "Just more practice", "A lot of one on one time", "A professional situation where I can apply what I learned".

Another question asked about what aspects of the workshop helped in changing the relevance of the topic, the answers aligned along four common functions: Specific examples, Showing the relevance explicitly, Relation made to the existing knowledge of participants and Firsthand experience of the skill. Examples include: "showed how you have to learn to follow the flow of the audience's attention", "It related some knowledge I knew to optimizations.", "I've only thought about abstracts for research papers, but I think they can be used in any place where a summary is needed", "Doing in hand".

As we explored the kinds of connections made by participants in these workshops by asking participants to identify two areas of applications, four themes emerged in the identification of the

application areas: Academic (course work related), Research, Professional and Personal goals. 29% participants found application in their research projects and 14% participants found application in their personal goals as seen in Fig 2.
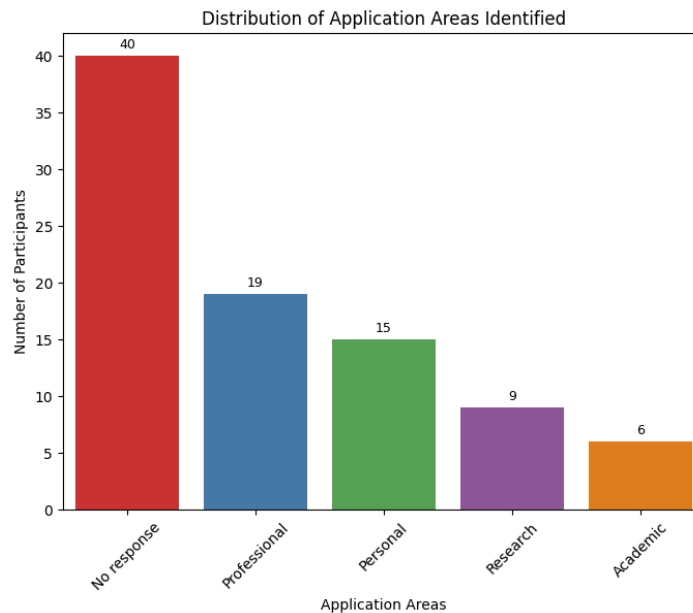

Fig 2. Application areas identified by participants

Another aspect of connection making was identification of valuable concepts in the workshops. Our results indicate that participants identified concepts that they perceived valuable taught in the workshops at mainly two levels of depth : General and Specific. There was almost an equal distribution of participants who identified more general concepts from the workshops and those who identified more specific, in-depth concepts. A few identified examples of general concepts are: "Learning how to engage the audience when they are most attentive" ; "Learned the basics of PyTorch"; "Deep learning - Starts off with simple features then goes into more complex layers of operations. Another was the core concepts of pytorch which were the tensor and the auto-differentiation." Examples of specific concepts identified as valuable by participants are: "organize components in folders, tailwind css for designing the app features"; "The Stigler Diet, concept of linear programming, how the optimal solution lies at the vertices"; "Ethos, pathos, and logos are in everything".

Correlation Analysis

Finally, we were interested to explore if there were any factors about the participants prior to workshop state and any factors about the workshop that played any role in the intent of application and confidence of application. For this purpose, we performed a correlation analysis,

followed by a group differences study and then we learned a regression model to find the variables that can explain our dependent variables : intent and confidence. The following sections explore the methods and results in detail.

We ran a Spearman Correlation test with only keeping the values where the p-values were <0.05[11].
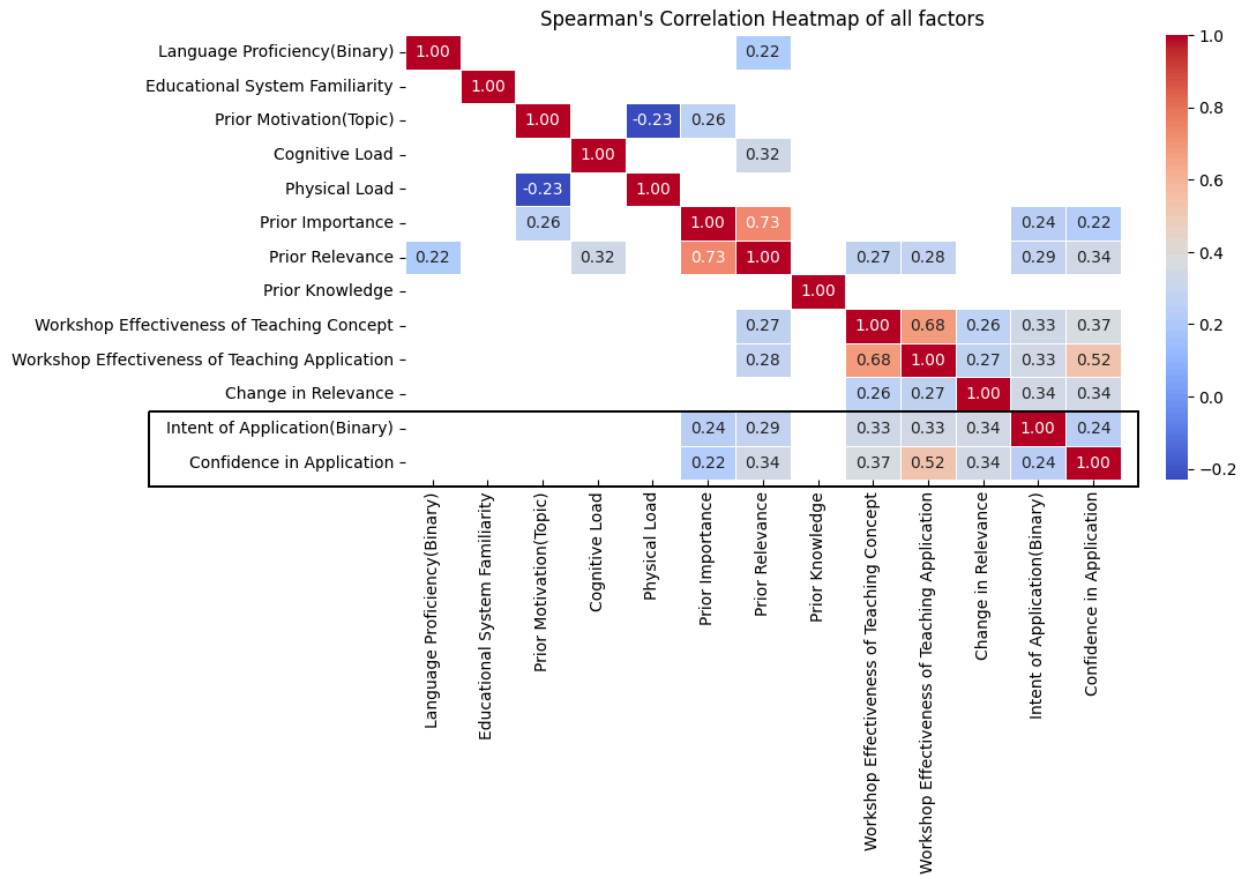

Fig 3. Spearman correlation values for pairwise ordinal variables.

From the correlation analysis, we found that the intent of application and confidence appears to be positively correlated with Prior Importance with a correlation factor of 0.24, Prior Relevance with 0.29, Workshop's role in teaching the concept with 0.33 (Fig 3.). The other significant correlation factors are listed in Table 5.

Factors	Intent of Application	Confidence in Application
Workshop's role in teaching the application of the topic	0.33	0.52
Workshop's role in teaching the topic	0.33	0.37

Workshop's role in change in relevance of topic	0.34	0.34
Prior Relevance	0.29	0.34
Prior importance	0.24	0.22

Table 5. Correlation between Factors and Intent and Confidence

Group Differences Analysis

Further analysis was conducted to understand how the different groups responded to the listed factors when the groups were formed based on the different workshop types, concept and application areas identification. To conduct this analysis, first the Kruskal-Wallis H test was conducted on the data separated by the groups formed based on the factors listed above [12][14]. This test identified the variables, where the groups had statistically significant differences. For groups where the p-value<0.05, a pairwise Dunn's test was conducted to identify specifically which groups were different by thresholding at a p-value for pairwise Dunn's test at 0.05 [13]. Finally, Cliff's delta was calculated between the groups that were identified to be significantly different to assess the effect size of the difference and a descriptive analysis was conducted to study the means and variances of these groups [15]. The tests used above were used keeping in mind the nature of data to be ordinal and non-parametric. The details of the group differences are shown in Fig A.1 of Appendix.

Inferences based on the Group Differences Analysis:
1. Participants who attended communication skills related workshops have reported higher averages than participants of technical skills related workshops on five aspects: Intent of application, Confidence in application, Change in relevance, Physical load and workshop's role in teaching the application of the concept in decreasing order of effect but still statistically significant difference between the two groups with effect size between (0.27,0.41).
2. Participants who highlighted specific concepts that they found valuable than those who identified more general concepts, reported higher on average on the following three aspects: Prior importance, change in relevance and Intent of application in decreasing order of effect size ranging between (0.24, 0.13).
3. There was no significant difference on any factor between the groups based on the application areas identified by the participants except for those who did not identify any application at all listed as no response in the figure above.

Regression Analysis

With the aim of understanding the role of the identified factors in predicting the Intent of participants and confidence of participants, we fit a Multinomial Logistic Regression individually for our two outcome variables being treated as dependent variables [12].

The regression model fitted for the dependent variable of Intent of Application explained the variance in the outcome with a measure of 0.3781, indicated by Pseudo McFadden R-squared value (Table A.1, Appendix). Based on this model, two factors were found to be statistically significant with P-values 0.052 and 0.025 respectively and coefficients 2.86 and 1.83 for Workshop's effectiveness in teaching the application and change in relevance. These two factors explained the change in participants reporting No intent to apply and the ones reporting a positive intent to apply.

Similarly, for the outcome variable Confidence in Application, four factors were found to be statistically significant in predicting the confidence of participants: Workshop's effectiveness in teaching the application, Prior Relevance, Change in Relevance and Prior Knowledge in the reducing order. Details of this model are available in Table A.2 of Appendix.

Conclusion

This study helps us get a better understanding of how students perceive and respond to the professional development workshops when provided in addition to the academic curriculum. Overall, we can conclude that the majority of students intend to apply what they learn in these sessions, and they find very broad applications of these skills including aspects of personal, professional, academic and research goals. There are similar aspects that impact both intent and confidence of being able to make connections between these workshops and their outside workshop goals. Factors related to both the students and the workshop play significant roles in this process. In the workshop related factors, it is extremely important to focus on making the workshop effective in teaching both the concept and the application via many tools like examples, hands-on practice, showing practical relevance. If there is a change in perceived relevance for students, they are more likely to feel confident and apply these skills elsewhere. On the student side, it is evident that presence of prior relevance and importance and the detail that a student finds valuable has a significant role to play in their intent and confidence of application. From the regression analysis, we can say that confidence in a student's application of skills acquired can be predicted via four factors: Workshop's effectiveness in teaching an application, change in relevance, prior relevance and prior knowledge in decreasing order. Student's intent of application can be explained weakly via change in relevance and workshop's effectiveness in teaching the application.

Future Work

This study indicated many interesting facets to the intent and confidence of being able to apply professional skills when taught in a setting of short duration voluntary workshops, especially the role of the workshop itself playing a significant role. This poses a natural question of what aspects in the structure of the workshop can we introduce that have a potential of bringing a positive impact on a student's ability to adopt and apply these skills. There are hints in student's responses that we will use to construct future workshops and investigate how a careful construction of a workshop helps in the outcome of the workshop. This study also necessitates the need to understand in more depth the relation of the multiple areas of projects and the multiple disciplines of these students and their successful application of learning of these skills.

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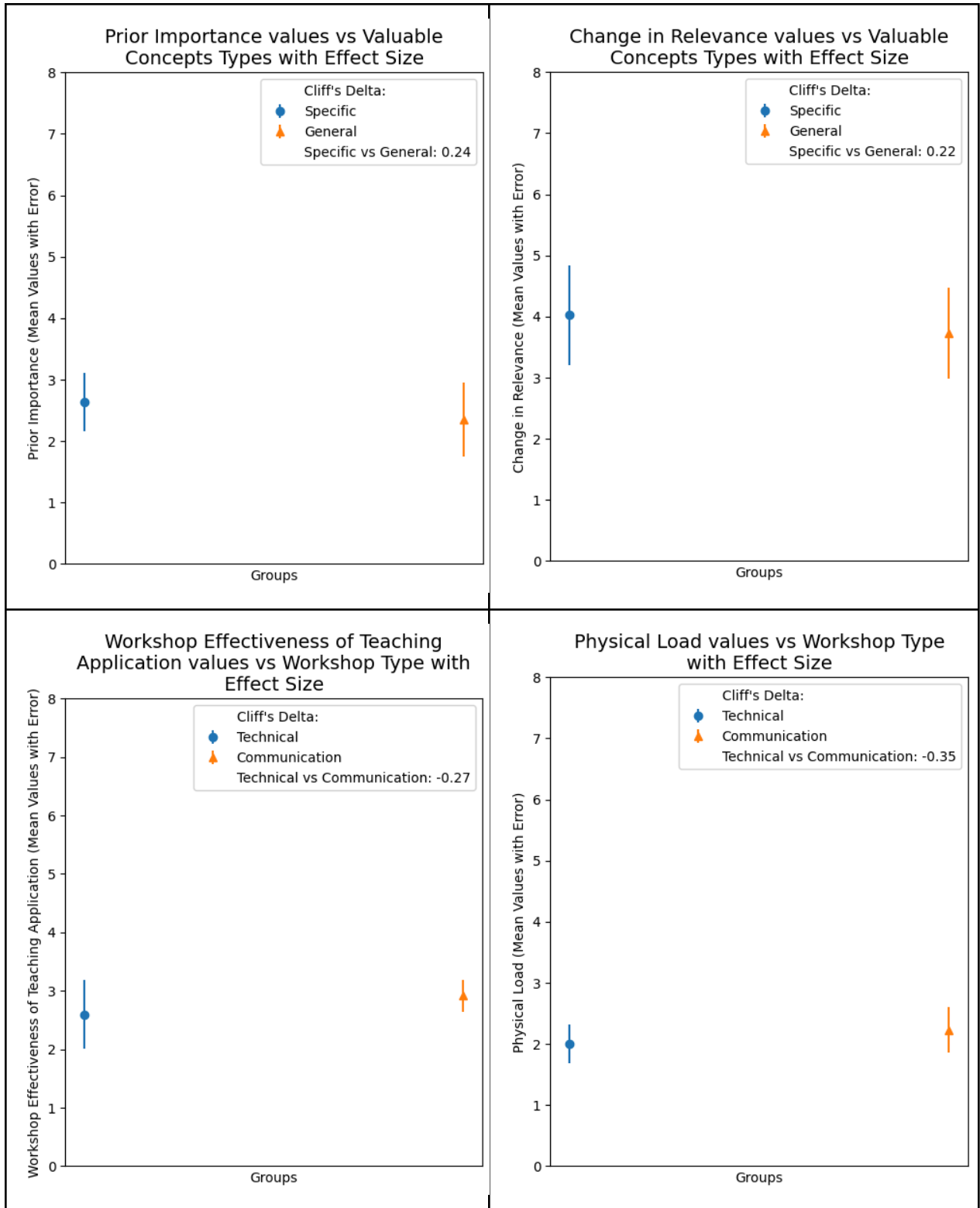
Appendix

Table A.1 : Multinomial Logistic Regression for Intent of Application

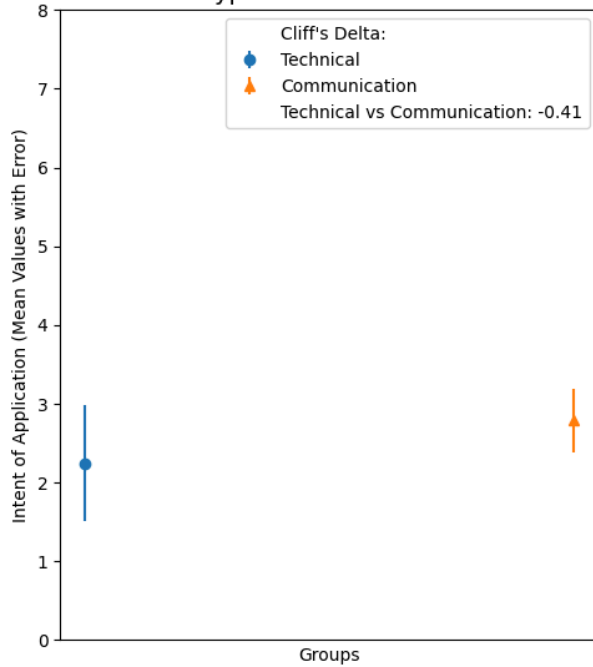| Ordinal Regression for Intent of Application: Pseudo R-squared (McFadden): 0.3781 Model coefficients: MNLogit Regression Results						
Intent of Application= "I'd like to but not confident"	**coef**	**std err**	**z**	**P>|z|**	**[0.025**	**0.975]**
const	-11.1981	6.965	-1.608	0.108	-24.85	2.453
Language Proficiency(Binary)	-0.1952	2.071	-0.094	0.925	-4.254	3.864
Educational System Familiarity	-1.0696	0.785	-1.363	0.173	-2.608	0.468
Prior Motivation(Topic)	1.0611	0.781	1.359	0.174	-0.469	2.591
Cognitive Load	-0.007	1.262	-0.006	0.996	-2.481	2.467
Physical Load	1.7928	1.669	1.074	0.283	-1.478	5.063
Prior Importance	1.1866	1.296	0.916	0.36	-1.353	3.727
Prior Relevance	1.0935	1.162	0.941	0.347	-1.184	3.371
Prior Knowledge	-0.6181	0.524	-1.179	0.239	-1.646	0.41
Workshop Effectiveness of Teaching Concept	1.6005	1.169	1.369	0.171	-0.69	3.891
Workshop Effectiveness of Teaching Application	-0.0328	1.044	-0.031	0.975	-2.079	2.013
Change in Relevance	0.7021	0.717	0.979	0.327	-0.703	2.107
Intent of Application= Yes	**coef**	**std err**	**z**	**P>|z|**	**[0.025**	**0.975]**
const	-33.8257	9.39	-3.602	0	-52.23	-15.421
Language Proficiency(Binary)	1.8736	2.455	0.763	0.445	-2.938	6.685
Educational System Familiarity	-0.5642	0.813	-0.694	0.487	-2.157	1.028
Prior Motivation(Topic)	1.022	0.84	1.217	0.224	-0.624	2.668
Cognitive Load	0.4784	1.325	0.361	0.718	-2.119	3.075
Physical Load	2.2248	1.647	1.351	0.177	-1.002	5.452
Prior Importance	1.5293	1.318	1.16	0.246	-1.054	4.113
Prior Relevance	1.5847	1.216	1.303	0.193	-0.799	3.969
Prior Knowledge	0.1492	0.571	0.261	0.794	-0.97	1.269
Workshop Effectiveness of Teaching Concept	1.2864	1.359	0.946	0.344	-1.378	3.95
Workshop Effectiveness of Teaching Application	2.8608	1.475	1.94	0.052	-0.029	5.751
Change in Relevance	1.839	0.821	2.239	0.025	0.229	3.449

Table A.2: Multinomial Logistic Regression for Confidence in Application

Ordinal Regression for Confidence in Application:
Pseudo R-squared (McFadden): 0.4405
Model coefficients: MNLogit Regression Results

Confidence in Application=Somewhat Confident	coef	std err	z	P>|z|	[0.025	0.975]
const	59.741	877000	6.81E-05	1	-1720000	1720000
Language Proficiency(Binary)	-33.1278	439000	-7.55E-05	1	-860000	860000
Educational System Familiarity	-2.8411	1.485	-1.913	0.056	-5.752	0.07
Prior Motivation(Topic)	-0.8905	0.938	-0.95	0.342	-2.728	0.947
Cognitive Load	-2.3891	2.076	-1.151	0.25	-6.458	1.68
Physical Load	-3.8758	2.762	-1.403	0.16	-9.288	1.537
Prior Importance	-2.8171	2.08	-1.354	0.176	-6.894	1.26
Prior Relevance	4.1575	2.009	2.07	0.038	0.22	8.095
Prior Knowledge	1.7804	0.899	1.98	0.048	0.018	3.543
Workshop Effectiveness of Teaching Concept	-0.628	1.1	-0.571	0.568	-2.784	1.528
Workshop Effectiveness of Teaching Application	6.0619	2.285	2.653	0.008	1.584	10.54
Change in Relevance	2.5344	1.146	2.212	0.027	0.288	4.78

Confidence in Application= Extremely Confident	coef	std err	z	P>|z|	[0.025	0.975]
const	-12.385	8440000	-1.47E-06	1	-16600000	16600000
Language Proficiency(Binary)	-2.5934	4220000	-6.14E-07	1	-8280000	8280000
Educational System Familiarity	-2.8709	1.537	-1.867	0.062	-5.884	0.142
Prior Motivation(Topic)	-1.5609	1.067	-1.463	0.143	-3.651	0.53
Cognitive Load	-2.8974	2.138	-1.355	0.175	-7.087	1.292
Physical Load	-4.3159	2.876	-1.501	0.133	-9.953	1.321
Prior Importance	-2.0971	2.222	-0.944	0.345	-6.452	2.258
Prior Relevance	4.8625	2.204	2.206	0.027	0.543	9.183
Prior Knowledge	1.9424	0.942	2.062	0.039	0.096	3.789
Workshop Effectiveness of Teaching Concept	0.6389	2.168	0.295	0.768	-3.61	4.888
Workshop Effectiveness of Teaching Application	6.3759	2.898	2.2	0.028	0.696	12.056
Change in Relevance	3.6663	1.26	2.91	0.004	1.197	6.136

Fig A1. Pairwise group differences with effect size

Workshop Effectiveness of Teaching Application values vs Application with Effect Size

Cliff's Delta:
No Response
Professional
Personal
No Response vs Professional: -0.43
No Response vs Personal: -0.47
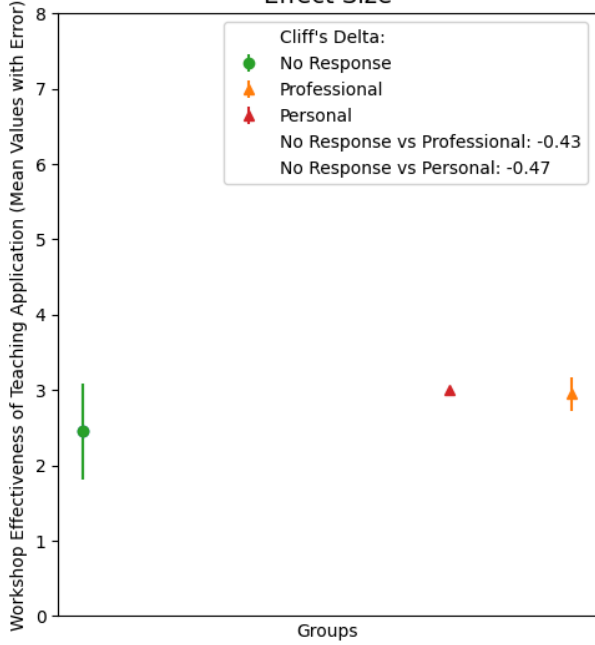
Workshop Effectiveness of Teaching Concept values vs Application with Effect Size

Cliff's Delta:
No Response
Professional
No Response vs Professional: -0.35
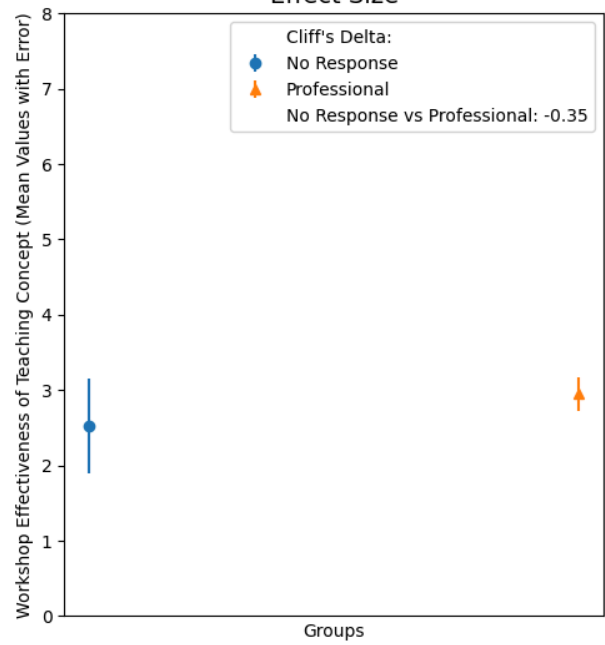
Language Proficiency values vs Education_Fam_type with Effect Size

Cliff's Delta:
US
Outside US
Outside US(International School)
US vs Outside US: 0.61
US vs Outside US(International School): 0.64
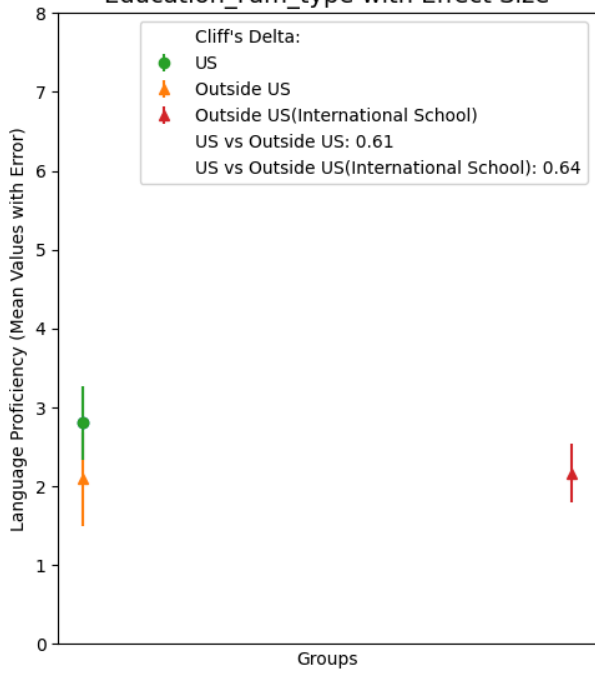
Language Proficiency values vs Application with Effect Size
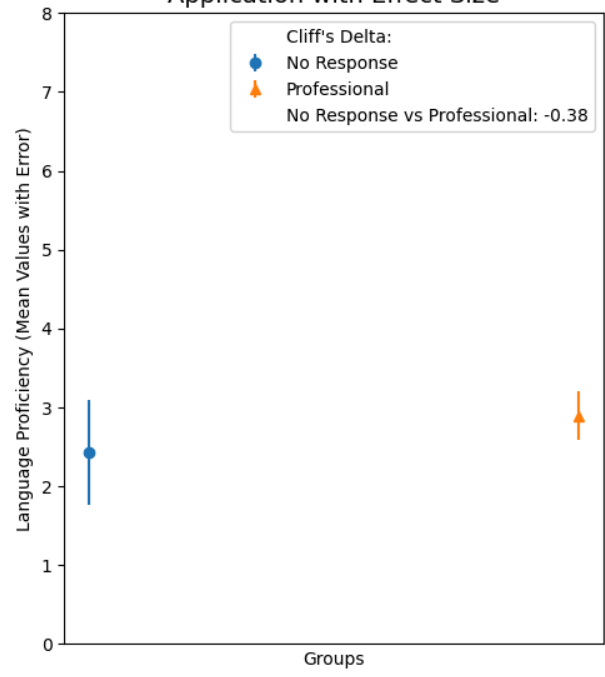
Cliff's Delta:
No Response
Professional
No Response vs Professional: -0.38

Intent of Application values vs Application with Effect Size

Cliff's Delta:
- No Response
- Research
- Professional
- Academic
- Personal

No Response vs Research: -1.00
No Response vs Professional: -1.00
No Response vs Academic: -1.00
No Response vs Personal: -1.00

Confidence in Application values vs Application with Effect Size

Cliff's Delta:
- No Response
- Research
- Professional
- Personal

No Response vs Research: -0.64
No Response vs Professional: -0.43
No Response vs Personal: -0.65
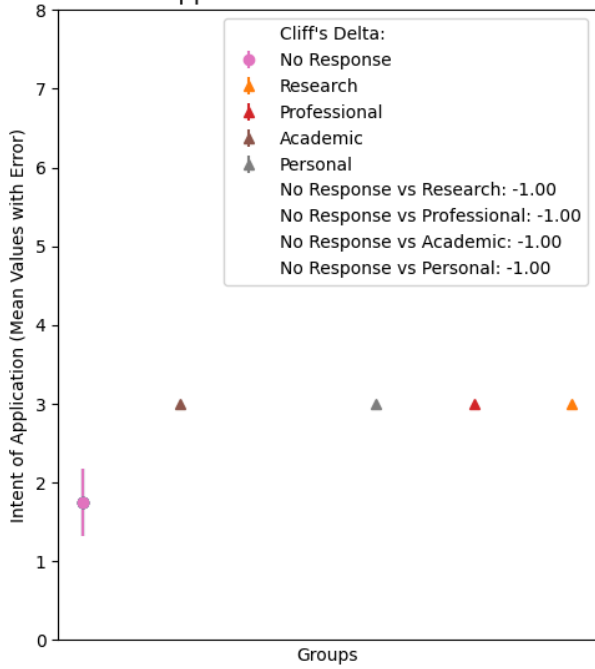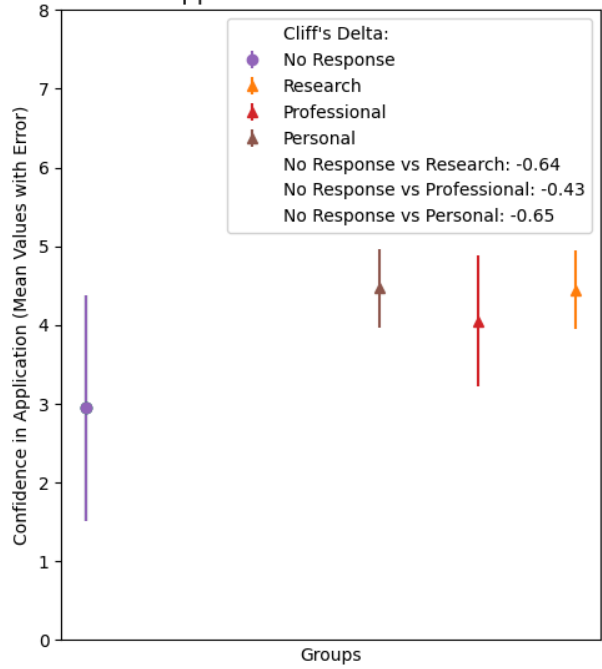
Change in Relevance values vs Application with Effect Size

Cliff's Delta:
- No Response
- Personal

No Response vs Personal: -0.48