Motivation and Learning Strategies - What can university engineering design courses do to help students and what must students do?

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Abstract

Engineering design courses attempt to teach students how to design products and services that address problems in the real world. We investigate the role that motivation and learning strategies play in the learning of design skills, taught in a higher education setting, but requiring team-based design project activities and interaction with external clients. We measure motivation for a total of 155 students across multiple concurrent sections of English-speaking students in a first-year engineering design course, using separate cohorts of students in five distinct school terms. The mode of instruction of the school terms ranges from fully online through Hybrid Flex (HyFlex) to fully in person. Due to the global COVID-19 pandemic restrictions, the 2021 Fall term course offering was held completely online, while the 2022 Winter term offering of the same course used a HyFlex teaching model. The course offering began its transition to a fully in-person mode in Fall 2022, and was completely in person for the remaining 2023 Winter and 2024 Winter terms. Each cohort of students was surveyed at the end of their term.

We use Pintrich's Motivated Strategies for Learning Questionnaire (MSLQ) and analyze the results to determine variations in the levels of motivation and study strategies of the different cohorts and course sections. We analyze statistically significant correlations and differences between the online, HyFlex and in-person versions of the course and examine variations in student motivation across the different sections of the same course, as taught by different instructors. The participation rate in the student survey varied between 18% and 26% of the total class size, making only certain statistical analysis methods and types of inferences appropriate.

Keywords

"Motivation", "Learning Strategies", "synchronous online", "remote learning", "HyFlex", "in-person", "MSLQ"

Acknowledgement

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Introduction

Intrinsic motivation can be viewed as the set of internal forces that drive people to behave in different ways and is the result of both the personality and the abilities of the individual, combined with their previous experiences [1]. These intrinsic motivation factors co-exist with other (extrinsic) motivating factors, such as grades, for students. Measuring motivation is difficult, because it varies with the individual and can even vary with a specific individual over time [2, 3].

Further, subtle extrinsic factors that are present in the environment influence both types of motivation. Indeed, the effects of such factors can be hard to separate from each other, too, when self-assessment tools are being used. Despite these concerns, we use self-reported data to identify the significance of intrinsic motivation, as it affects activities in a team-based, project-based engineering design course for first-year students. We want to determine whether other factors associated with near-“authentic” (i.e. a design problem with a real-world client) engineering design tasks are correlated with motivation scales such as intrinsic motivation. For this purpose, we use a survey mechanism, initially created by Pintrich et al., called the “Motivated Strategies for Learning Questionnaire (MSLQ) [4].

MSLQ attempts to quantify the levels of both intrinsic and extrinsic motivation and learning strategies in subjects and was originally defined specifically for an academic environment. MSLQ relates motivation to higher cognitive functions (e.g., those relating to organization, peer learning, critical thinking, as well as a few others). The survey tool has been adapted for other environments [5, 6] but has been criticized by researchers and shown to be inaccurate or unreliable in certain situations [5, 7, 8]. Nevertheless, the method continues to be used, and this persistence is in part because the results can be analyzed at different levels, as will be explained in more detail later.

The paper is structured into three basic sections. The experimental conditions are explained in Section 1. The surveyed results are then presented in Section 2 and analyzed in Section 3. Based on this data analysis, conclusions are drawn, and possible future work is discussed.

Ethics approval for this research project was duly obtained from the University of Ottawa Research Ethics Board (REB), under file number H-02-24-10020.

Description of Experimental Method

During this study, in the GNG1103 - ”Introduction to Engineering Design” course at the University of Ottawa, students were taught engineering design in three concurrent course sections, each led by a different instructor. Data was gathered over five distinct terms with different cohorts of students. The course is offered in both English and French. In the Fall 2021 term, there were three different instructors: A, B and C, with class sizes that varied from 63 to 84 students, depending on the specific section. For the Winter and Fall 2022 terms, instructor C was replaced by a new one, D, to create a new set of instructors: A, B and D. Replacing the third instructor each time, the 2023 Winter term instructor set became: (A, B, E) and then changed to (A, B, F) in the final 2024 Winter term. The details of the course sections are given in Table 1.

All course assessments, lecture content, and lab content are kept identical for students in each of the different sections, although there are natural variations in style and delivery with different instructors. There is a single final exam for all course sections. The design project topic is a continuous project throughout the term in which the students work with a client to address real-world problems. For example, the project could be designing an automated farm weeder or a robot to provide guided museum tours.

Table 1: Nature of Learning Environment

Term (Instructors)	Instruction Mode			Course Date	Survey Date
	Synchronous Lectures	Labs	Group Project Work		
2021 Fall (ABC)	Online	Mostly Online	Online	Sep. - Dec. 2021	Nov./Dec. 2021
2022 Winter (ABD)	HyFlex	HyFlex	HyFlex	Jan. - Apr. 2022	Mar./Apr. 2022
2022 Fall (ABD)	Mostly In-Person	Fully In-Person	Fully In-Person	Sep. - Dec. 2022	Dec. 2022
2023 Winter (ABE)	Fully In-Person	Fully In-Person	Fully In-Person	Jan. - Apr. 2023	Apr. 2023
2024 Winter (ABF)	Fully In-Person	Fully In-Person	Fully In-Person	Jan. - Apr. 2024	Dec. 2024

The design project topic varies with each course section, but is identical for all students in a particular course section. Within a specific course section, project teams are organized into groups of four to five students, to work on the project together. This structure allows them to collaborate with their peers to enhance their learning experience. A student project manager and a graduate student teaching assistant are assigned to each team. The project manager, a senior student, who has already taken the course, actively engages with the team to offer design feedback and to provide mentorship for the management of the team's schedules and timelines. The teaching assistant offers general evaluative feedback regarding the team's overall progress and assesses their deliverables, such as their weekly group assignments.

During the pandemic, all students in each section wrote a final exam at the same time, with questions drawn randomly from large question pools, resulting in no two exams being exactly the same. This randomization was carried out in an attempt to reduce plagiarism. A significant portion of a student's grade for the course (45%) is derived from their performance on the group-based project deliverables, while the rest is determined from individual assessments (e.g., exams, quizzes, reflective essays, etc.). There are a total of five quizzes in the course, distributed throughout the term. A portion of each quiz is a formative take-home essay assessment, where students are allowed to access external resources in a lower-stress environment. The final exam is structured in the same way as these quizzes and functions as a summative assessment performed ”live” using a Learning Management System (LMS).

Five distinct cohorts of students were surveyed for this research study. The first cohort of three course sections of students attended lectures synchronously, working in groups in an environment that was completely online (because of the COVID-19 global pandemic) in the Fall of 2021. Students were surveyed after the course was complete, but before final grades were announced.

In the Winter of 2022, except for the very first month of the term, which was also held completely online, the second cohort of three course sections of students studied and worked in a hybrid and flexible learning environment (i.e., 'HyFlex'). In the HyFlex offering of the course, students could choose to attend either “in person” or online for any or all the course components (i.e. lectures, labs, or group project work). The instructors taught a concurrent mixture of online and in-person students in their lectures. The Teaching Assistants provided the same kind of supervision and instruction during the lab sessions.

In both online and HyFlex terms, students were asked to attend lectures synchronously, but had the option of watching a video recording of the lecture later, asynchronously. Although asynchronous attendance was possible, it was actively discouraged, given the large amount of interactive group activity built into the course lectures, labs, and group work. Online versions of all labs were provided for the entire durations of both online and HyFlex terms. In addition, course projects were selected with a greater software component than was typical, in terms prior to 2020.

The survey was repeated in the 2022 Fall term, where the mode of instruction was “mostly in-person”. While the primary mode of instruction was synchronous and “in-person”, a few students, forced to remain abroad due to the pandemic, were given the opportunity to attend lectures online. The remaining course components, other than the lecture, were “fully in-person”. The final two terms, the 2023 Winter and 2024 Winter terms, had all of their course components “fully in-person”.

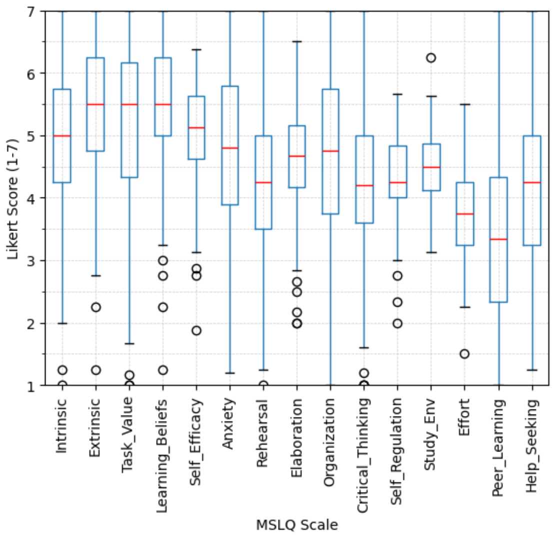
A “continuous improvement” process has been used to optimize GNG1103 course content, since its inception in 2016. However, by 2020 90% of the lecture content and course structure was stable with minor modifications being made, on a term by term basis. Interestingly, the COVID pandemic created some interesting new possibilities, in terms of computer-based collaborative work, but many or most of these have been replaced, in turn, with more “live” alternatives, as pandemic restrictions were eased.

All questions were identical in the surveys for all cohorts and across all course sections. We measure the levels of both student motivation and learning strategies under the different online/HyFlex/in-person working conditions for each set of students. We analyze the data across sections, looking for statistically significant differences in the results, based on the specific section instructor and/or project topic (Table 1). Initially, data was collected as part of the “continuous improvement” effort, but ethical review and approval was obtained in the final year for the “secondary purposes” outlined in this paper.

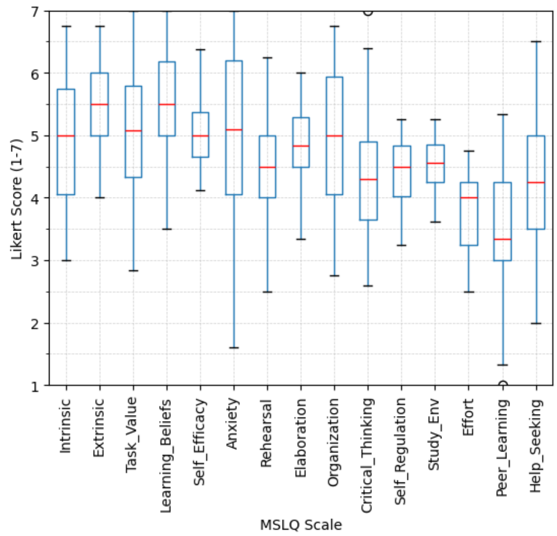
Results

A standard MSLQ survey consists of 81 survey items (i.e., questions) and is accompanied by a “manual” [4]. The items are assessed using a 7-point Likert scale that spans from “not at all true of me” to “very true of me”. The questions are grouped into a set of 15 “Scales”. For example, one of these scales is ‘intrinsic motivation’. A smaller set of “components” is then also defined, as a super-set of logically related groups of those same scales. For example, “extrinsic motivation”, “intrinsic motivation” and “task value” scales are all then grouped under a higher level “Value” component categorization. This categorization allows for a higher level of analysis to be performed.

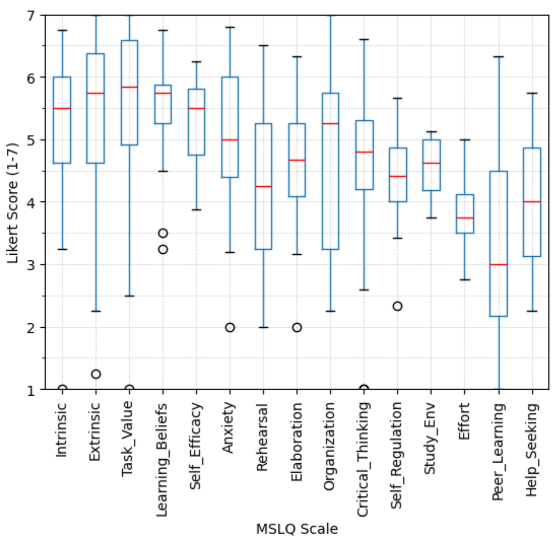
The MSLQ survey is notably comprehensive due to its extensive set of 81 questions. The estimated time to complete the survey is 15-20 minutes. A total of 167 students started our survey;



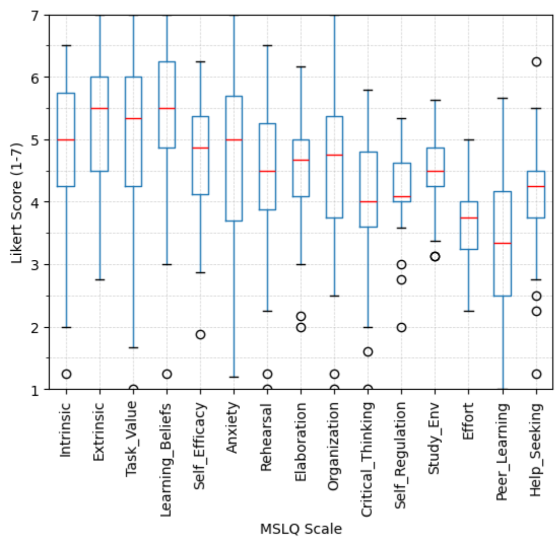
(a) All Cohorts Boxplot



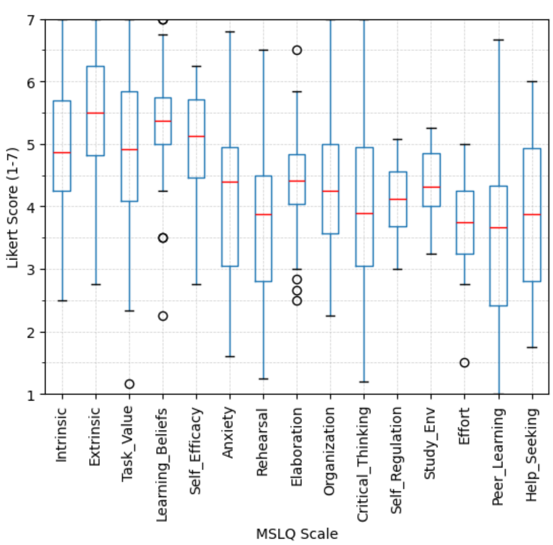
(b) 2021 Fall Term Boxplot



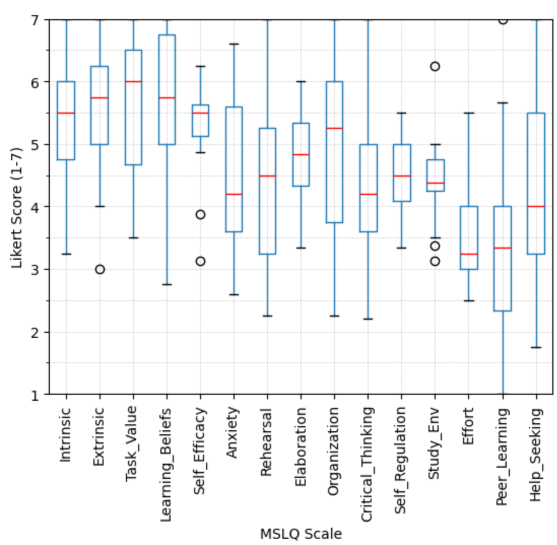
(c) 2022 Winter Term Boxplot



(d) 2022 Fall Term Boxplot



(e) 2023 Winter Term Boxplot



(f) 2024 Winter Term Boxplot

Figure 1: Term-wise Boxplots of MSLQ Scales (n = 155)

however, only 155 individuals successfully completed it, providing valid responses to all of the questions. The 7.19% dropout rate includes those students who provided incomplete responses to any of the 81 items on the Likert scale. All such data were excluded from our analysis.

The Shapiro-Wilk test was performed for each scale, and the results indicated that the data followed a normal distribution. The median values of the entire cohort, taken over all terms, are presented in Figure 1a. Overall, students had above-average scores on the motivation and learning strategy scales. The notable exception was the peer learning scale, with a mean of 3.363 (SD = 1.363). Interestingly, this result is consistent with Pintrich's original work [4], but is of concern, given the intended peer-based, project-based, learning model for the first-year engineering design course.

Table 2: ANOVA Results for Various MSLQ Scales and Components

MSLQ Component	**MSLQ Scale**	**Sum of Squares**	**F-value**	**p-value**
Value	Intrinsic Motivation	5.733	1.101	0.358
	Extrinsic Motivation	2.898	0.620	0.649
	Task Value	10.847	1.584	0.181
Expectancy	Learning Beliefs	2.238	0.526	0.717
	Self Efficacy	7.938	3.291	**0.013***
Affective	Test Anxiety	14.348	2.007	**0.096**
Cognitive & Metacognitive Strategies	Rehearsal	7.110	1.177	0.323
	Elaboration	4.604	1.626	0.171
	Organization	5.875	0.891	0.471
	Critical Thinking	6.948	1.258	0.289
	Self-Regulation	3.331	2.189	**0.073**
Resource Management Strategies	Study Environment	0.491	0.463	0.763
	Effort Regulation	0.983	0.556	0.695
	Peer Learning	0.407	0.055	0.994
	Help Seeking	2.531	0.486	0.746
Significant p-values lesser than α = 0.05 are marked with * p-values lesser than 0.10 are in **bold**				

To observe differences between our different modes of instruction, we perform a one-way Analysis of variance (ANOVA) test. This allows us to observe any variations in the MSLQ scales across the various terms. Table 2 shows the values for an ANOVA analysis of the MSLQ scales and the MSLQ components taken over all students surveyed. The ANOVA test, performed across terms, for the peer learning dependent variable was not significant, which means that remote learning does not explain the discrepancy in the mean value of peer learning. Previous studies [9] also observed low values for peer learning, compared to other MSLQ scales. Therefore, this pattern might be a defect/feature of the tool or a larger trend in education, rather than being related to specific variation observed in our study (e.g., because of COVID) with first-year engineering design students.

Correlation of MSLQ Scales

The correlation between the different MSLQ scales is assessed to analyze the relationship between the various aspects of student motivation and learning strategies within the context of our design course. Cronbach's alpha (α) measures internal consistency and was calculated for the entire dataset, for all cohorts. The resulting value of 0.854 indicated good internal consistency [10]. The pair-wise Pearson correlation coefficient (r) was calculated between each MSLQ scale as shown in Figure 2. Only coefficients with significant values are shown as text, but colour is used to indicate the specific value regardless.

An initial α value of 0.05 was used to reject the null hypothesis and evaluate statistical significance. To account for potential Type I errors introduced by repeated comparisons, the p-value was further adjusted using Bonferroni's correction to 0.000476.

The strength of correlation was defined by the metrics defined in [11]. The intrinsic motivation scale was found to be strongly correlated with the measure of task value, which might not be surprising. This strong correlation indicates that students who have a high intrinsic goal orientation found the engineering design course material to be of high interest and utility, participating in course activities out of curiosity and/or a desire for mastery [4], rather than due to external factors, such as grades. Originally, in Pintrich's work, these scales were compared with graded outcomes only, rather than as a correlation between the scales.

Furthermore, these students had a moderate positive correlation with their Control of Learning Beliefs and Metacognitive Self-Regulation scales. This moderate correlation implies that such students felt that their outcomes in the course depended on factors that they could control. Such controllable factors might be: studying habits of planning, monitoring, and regulation, as well as other existing skills, related to self-control.

Students who scored highly on the Metacognitive Self-Regulation scale were also more likely to be organized in their study methods and employ elaboration strategies during their study. They believed that they had built systematic connections between the knowledge that was being absorbed, rather than purely reciting back course material. This correlation should not vary by semester or by instructor, but we will analyze this pattern in the following sections. For each term in the study, the medians, inter-quartiles, minima and maxima are shown (as well as the identified outliers) are all shown in Figure 1.

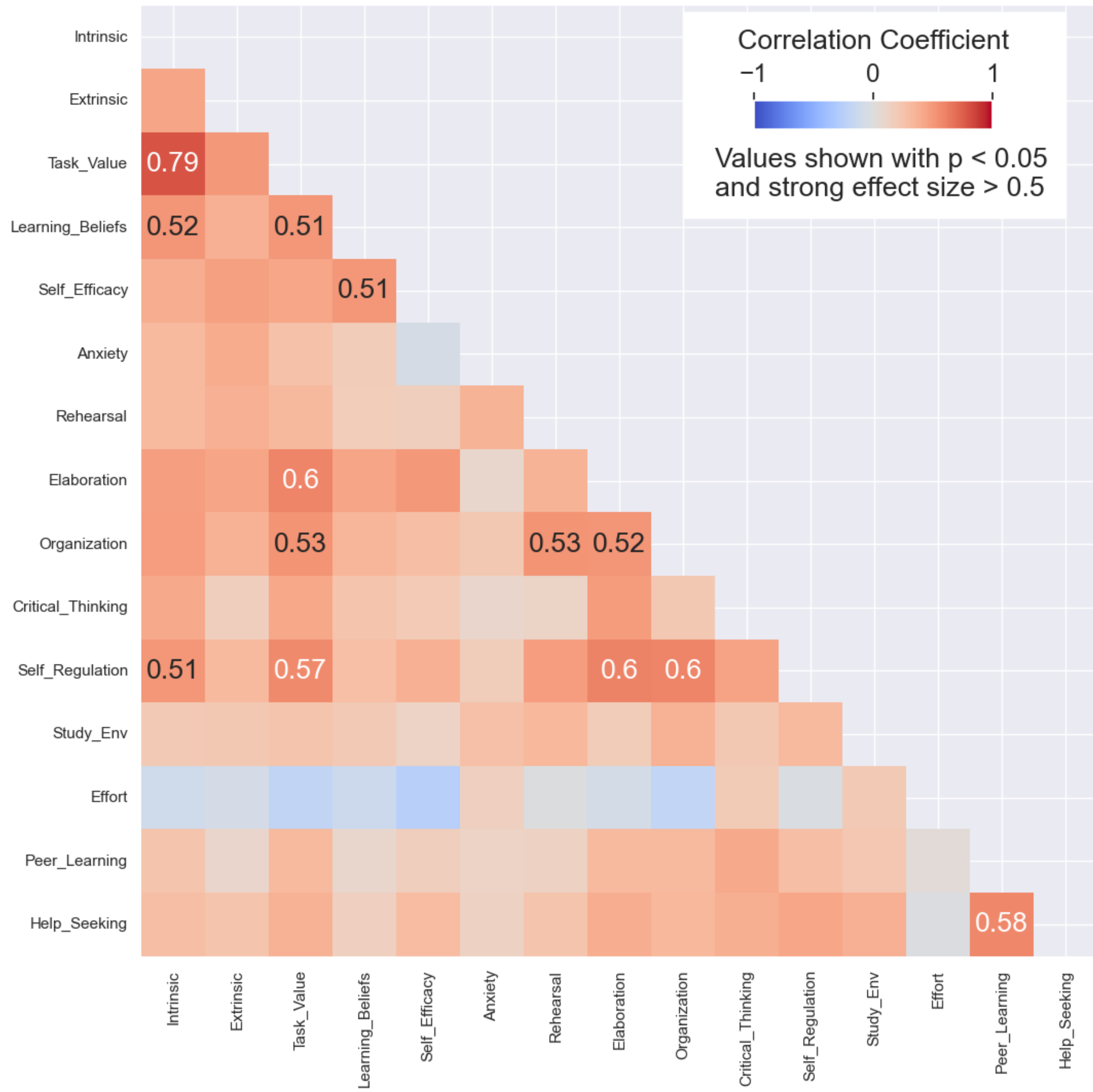


Figure 2: Overall Correlation Matrix for MSLQ Scales

In our experiment, all of the first-year engineering design students, who valued the course highly, were more likely to use elaboration strategies for studying, rather than using rehearsal methods. Unsurprisingly, students who prefer to study in groups with their peers were also more likely to seek out help. This help could come either from those other students or from the instructor, or from a senior student (e.g., a teaching assistant or student project manager) when they faced difficulty with the learning material or with the implementation of it as a final design prototype.

Differences Between Modes of Instruction

The value of Cronbach's alpha (α) was calculated individually for each term and shown in Table 3. While these α values indicated acceptable internal consistency for the fully online Fall 2021 term, all subsequent terms also had strong internal consistency.

Table 3: Cronbach's Alpha (α) for each term

Term	**Cronbach's Alpha (α)**
Fall 2021	0.674
Winter 2022	0.871
Fall 2022	0.834
Winter 2023	0.862
Winter 2024	0.904

Indeed, examining Figure 1, the average values are remarkably consistent across all terms (i.e., all three instruction modes and all six instructors). A one-way ANOVA test was performed across all five terms to observe significant variations in means for all scales to observe differences between the modes of instruction. The ANOVA test was performed with an alpha value (α) of 0.05. The results from this test are presented in Table 2. A couple of results are more significant, based on their F-Score and corresponding p-value.

Most notably, self-efficacy varies significantly across terms, with an F value of 3.290 and a p-value of 0.012. Tukey's HSD test was used to find the semesters of variation for the self-efficacy scale. The results are plotted in Figure 3. The confidence interval was set to 95%.

In Tukey's HSD graph in Figure 3, self-efficacy rises during the transition from the online to the HyFlex term, but falls sharply in the transition to the in-person term, before rising again in subsequent terms. Students seem to be relatively confident in their ability in the online term. There is an increase in self-efficacy in the HyFlex term, perhaps due to increased familiarity with the remote learning environment.

However, there is a drop in self-efficacy in the Fall 2022 term, during the transition back to fully in-person instruction modes. As modes of student instruction switched back to being fully in person, students seemed to have been able to regulate themselves better, and the change in the correlation value between self-efficacy and self-regulation is significant. This trend is most noticeable between the cohort of students who were just starting at university, having done their final years of high school with online learning environments, and those who had already completed one university term in person.

Overall, between the 2022 Fall term and the 2024 Winter term, there is a significant difference (difference in the means of 0.634) with a p-value of 0.013, and a 95% CI [0.094, 1.173]. Perhaps students were then confident in their abilities in the now-familiar in-person mode of instruction, as opposed to being in a transition state of "mostly" in-person instruction, as the world emerged

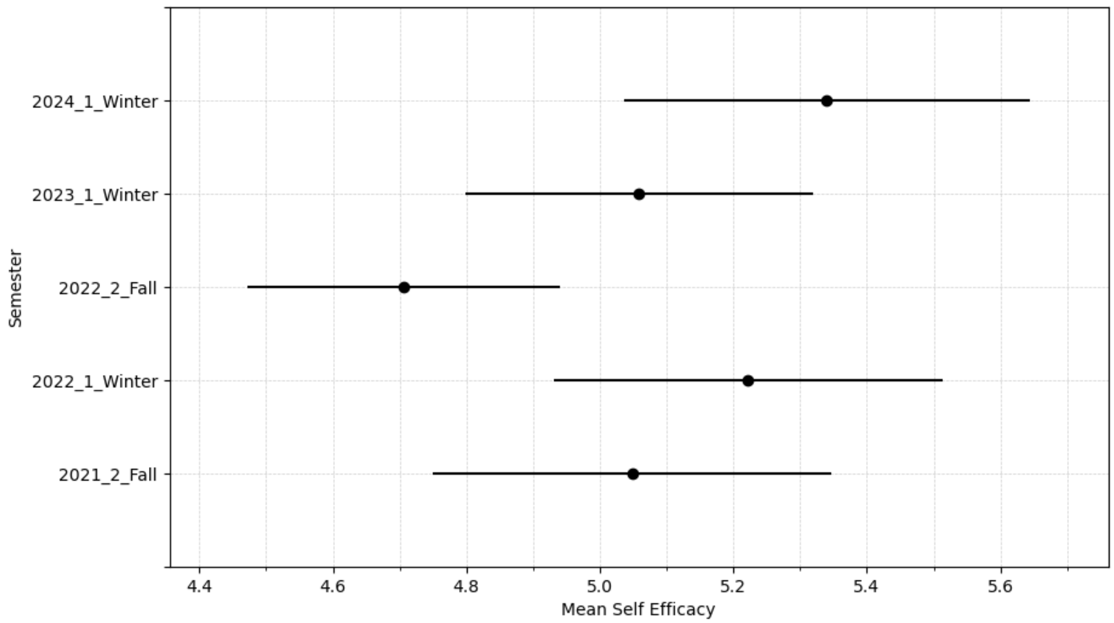


Figure 3: Tukey's HSD Test for Self-Efficacy, by term, with confidence interval for each mean

from the COVID-19 pandemic. The group-based course organization (as well as the focus on "hands-on" learning in the project and labs and lectures) of the first-year engineering design course could have accentuated these differences even more.

The improvement in self-efficacy between the 2021 Fall and 2022 Winter terms is interesting. In fact, the levels in the 2022 Winter term are higher than those in the two subsequent terms, each of which had in-person formats. If subsequent terms had also been conducted online, the trend of self-efficacy might have continued to increase, but there is no way to confirm this trend. The one-way ANOVA test for the self-regulation scale was found to have a p-value of 0.073, close to the specified significance level of 0.05. The Tukey HSD test was performed for this scale, but no significant differences were observed between these other terms.

To examine the differences in correlation across the different modes of instruction, the correlation matrix was calculated for each individual term. The correlation matrices were transformed using Fischer's Z transformation, to normalize the distribution. For each pair of terms, the corresponding MSLQ scales in the Z-score matrices were compared, as shown in Figure 4. A critical value of ± 1.96 was considered for analysis, which corresponds to a two-tailed p-value of 0.05.

Fischer's Z-test revealed statistically significant differences in the correlation between the Intrinsic and Extrinsic motivation scales across terms. Specifically, the Z-test values were -4.994 (2021 Fall and 2022 Winter), 3.77 (2022 Winter and 2022 Fall) and -2.019 (2023 Winter and 2024 Winter terms). The correlation spikes at 0.85 for the 2022 Winter term. During this HyFlex term, the prevalence of dual-motivated students was particularly high. The correlation declines sharply to 0.28 during the transition to the in-person mode of instruction during 2022 Fall. As the students adapted back to the in-person mode of instruction, the value gradually increased to 0.38

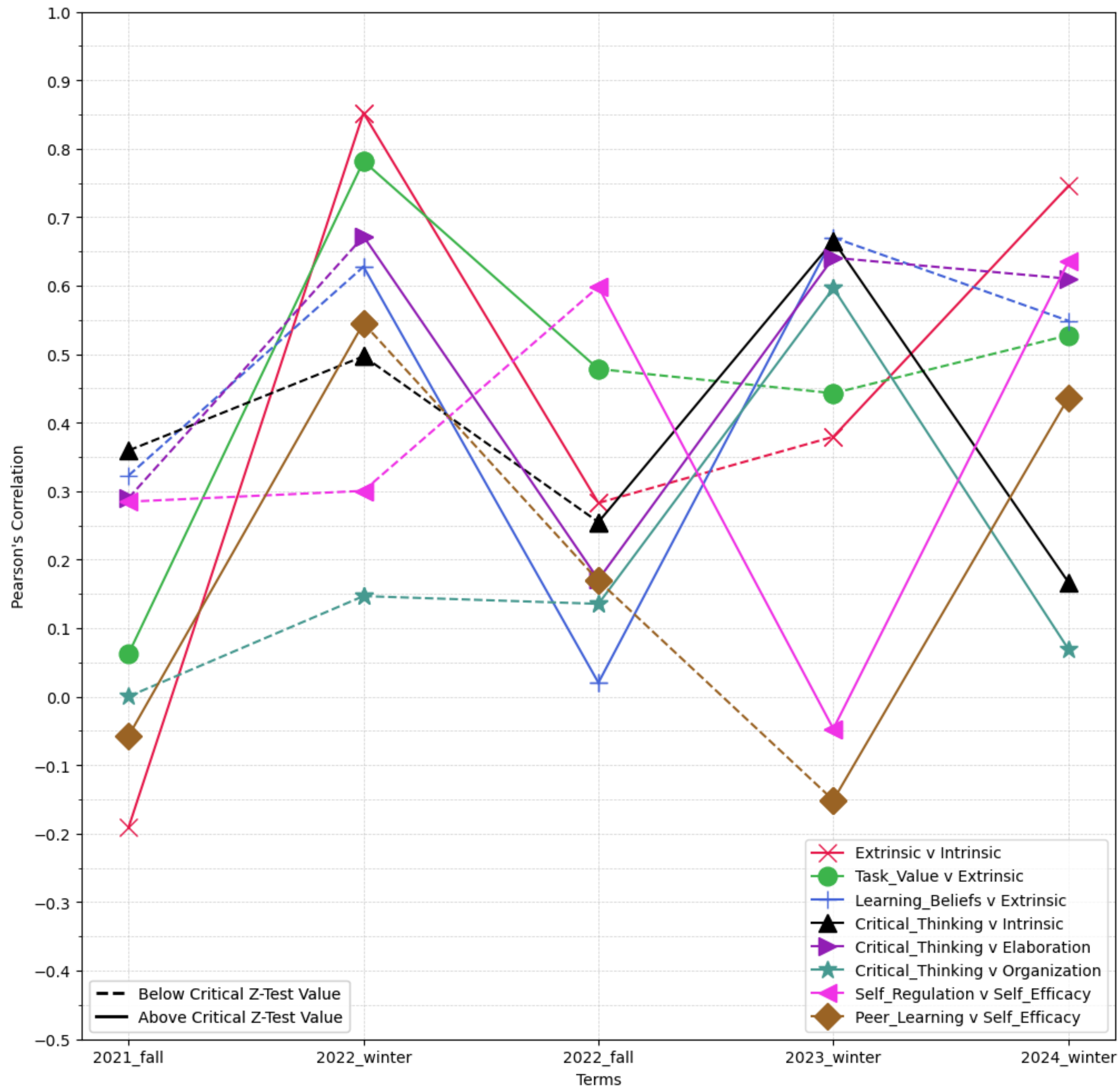


Figure 4: Significant Fischer's Z-Test Values for MSLQ Scale Correlation Pairs Plotted Term-Wise. Solid lines denote periods with critical Z-Test Values (see legend).

in 2023 Winter, and achieved a high correlation once again in 2024 Winter. This suggests that intrinsic and extrinsic motivation reinforced each other during the HyFlex term, whereas general uncertainties during the transition periods induced a decoupling of these scales, perhaps due to ambiguity of assessments and change in environment.

A comparable, but less pronounced, trend was observed between the Task Value and Extrinsic Motivation correlation pair. This pair describes the students who found the course to be valuable, along with external factors as a source of motivation. For this pair, the significant Z-test values were -3.382 (2021 Fall and 2022 Winter) and 2.048 (2022 Winter and 2022 Fall). These values reflect a sharp increase in correlation during the HyFlex term from 0.06 to 0.78, and a subsequent decline to a moderate value of 0.48 in the in-person term. The value remained relatively constant during the in-person terms.

The Control of Learning Beliefs and Extrinsic Motivation correlation pair reflects students who are motivated by external factors, but who also believe that their efforts in the course will be meaningful. The significant Z-test values were 2.778 (2022 Winter and 2022 Fall) and -3.306 (2022 Fall and 2023 Winter). This observation is caused by the fact that the high correlation value present in 2022 Winter decreased significantly during the 2022 Fall transition term, before significantly increasing again in the subsequent term. This decline indicates that extrinsically motivated students did not believe that their efforts would be meaningful in the course, during the transition.

For the Critical Thinking and Intrinsic Motivation pair, the significant Z-test values were -2.266 (2022 Fall and 2023 Winter) and 2.274 (2023 Winter and 2024 Winter). Generally, these two scales are positively correlated with each other, but there were two terms of low correlation, namely, 2022 Fall and 2024 Winter. In these terms, very few intrinsically motivated students also viewed themselves as critical thinkers. The Critical Thinking and Elaboration pair showed significant Z-test values of 2.484 (2022 Winter and 2022 Fall) and -2.453 (2022 Fall and 2023 Winter). This result can be attributed to an outlier of low correlation during the 2022 Fall term (0.171 correlation coefficient), which was the only term without a strong positive correlation. As with self-efficacy, it was observed that the 2022 Fall term bucked the trend and was the only term in which the Critical Thinking scale did not correlate with any other scale among the students. Figure 2 shows that intrinsically motivated learners are more likely to use Elaboration as a study method than rehearsal. It is within this cohort of students that the decline in Critical Thinking is observed during the transition term.

The 2023 Winter term saw a significant increase in the Critical Thinking and Organization correlation pair, with Z-test values of -2.304 (2022 Fall and 2023 Winter) and 2.216 (2023 Winter and 2024 Winter). The 2023 Winter term was the only term with a strong positive correlation for this correlation pair. In contrast, the correlation coefficient for Metacognitive Self-Regulation and Self-Efficacy was -0.05, which was the lowest among all terms. This observation is reflected in the Z-test values of 3.082 (2022 Fall and 2023 Winter) and -2.858 (2023 Winter and 2024 Winter).

The Peer Learning and Self-Efficacy correlation pair had significant Z-test values of -2.292 (2021 Fall and 2022 Winter) and -2.222 (2023 Winter and 2024 Winter). This trend is explained by the moderate positive correlation of 0.55 and 0.44 during the 2022 Winter and 2024 Winter terms, respectively. A similar increase is visible in Peer Learning correlations with both Rehearsal (-2.251) and Elaboration (-2.547) during the shift from online to a HyFlex mode of instruction.

Instructor-wise/ Project-wise Analysis

There were 6 distinct instructors (each leading classes with distinct projects) for this engineering design course, labeled A to F, as shown previously in Table 1. To analyze the differences among these instructors, a one-way ANOVA test is performed across all instructors to observe significant variations in the means for all scales. The ANOVA test is performed with an alpha value (α) of 0.05. The results show significant differences among only one pair of instructors, namely, A and B. The scales of variation are Extrinsic Motivation, Self-Efficacy, Elaboration, and Self-Regulation. In each of these scales of variation, instructor A scored on average 0.56 points above instructor B. There are no significant variations among any other pairs of instructors.

Component-wise Analysis

Using the five MSLQ components defined previously in (Table 2), namely: Value, Expectancy, Affective, Cognitive, and Resource Management skills, the overall results are shown in Figure 6a. As shown in Figure 5, students score higher on what Pintrich [4] calls "Motivation" scales (e.g., the Value, Expectancy, and Affective MSLQ components) than with "Learning Strategy" scales that are part of the Cognitive and Resource Management MSLQ components.

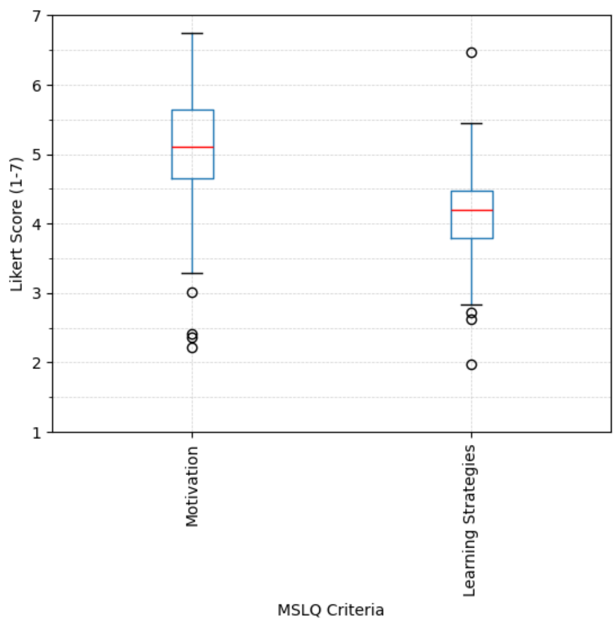
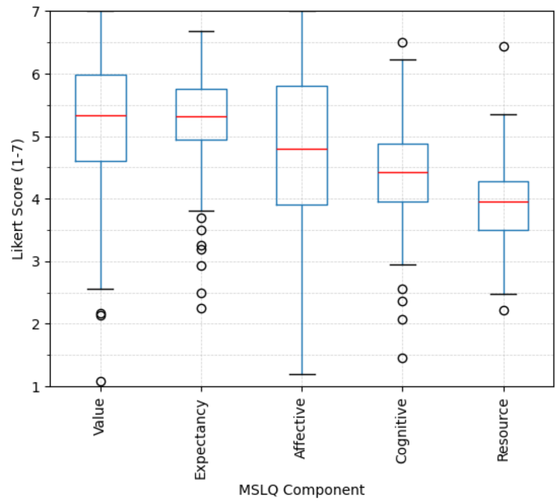


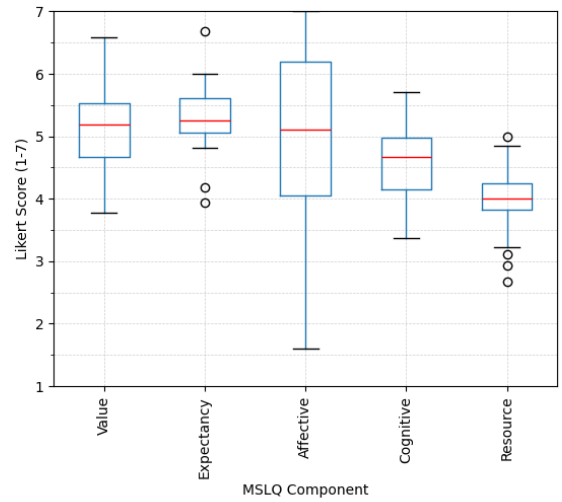
Figure 5: Overall Box plot of Motivation and Learning Strategies Criteria

Using a Shapiro-Wilk test to check for normality, the Motivation criteria are found to be not normal, with $p < 0.05$. Therefore, the Wilcoxon signed-rank test must then be used to assess whether the values come from the same (non-normal) distribution. The "Motivation" and "Learning Strategy" scales are significantly different, based on the Wilcoxon test value ($p < 0.05$). This finding is not unique to first-year engineering design students and is similar to the original study by Pintrich, which had students from several disciplines/faculties over all four years at a community college.

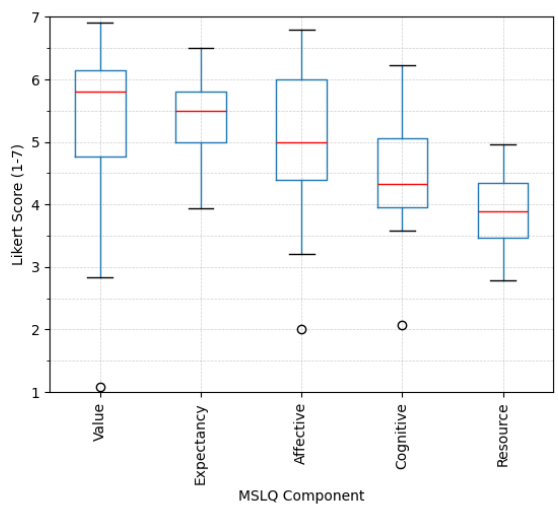
To observe differences between the MSLQ components across terms, a one-way ANOVA test was performed for each component across the various terms. No significant variations were found between the terms, using a p-value threshold of 0.05. However, the Affective component (basically identical to the 'Test Anxiety' scale) variance is noticeably larger than the other components, when examined across all terms. The median is consistently near a value of 5,



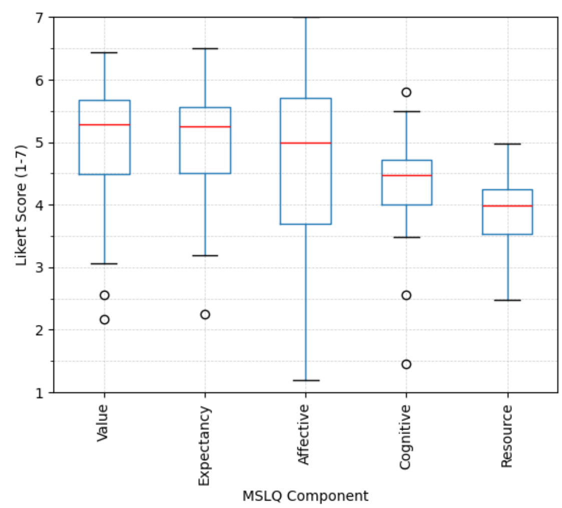
(a) All Cohorts Component Boxplot



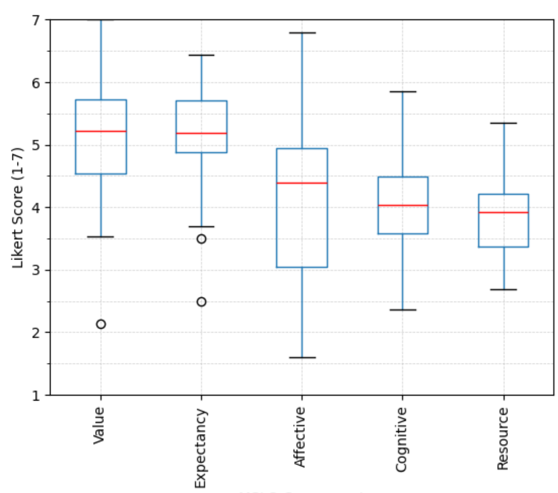
(b) 2021 Fall Term Component Boxplot



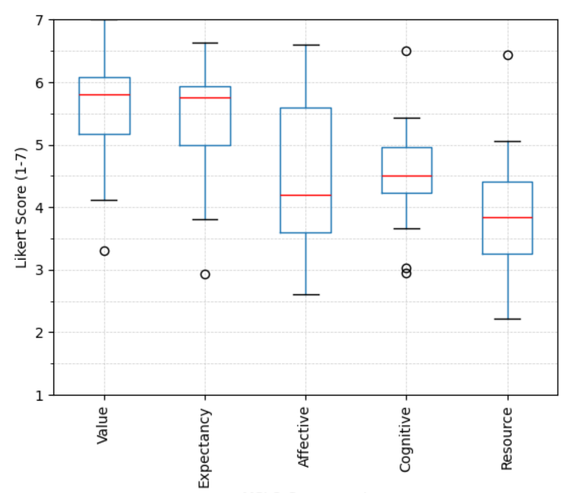
(c) 2022 Winter Term Component Boxplot



(d) 2022 Fall Term Component Boxplot



(e) 2023 Winter Term Component Boxplot



(f) 2024 Winter Term Component Boxplot

Figure 6: Term-wise Boxplots of MSLQ Components (n = 155)

dipping slightly in the two later in-person terms. This observation did not seem to be as true in Pintrich's original study, where the range of values is one point or more lower. Almost half of a student's grade in GNG1103 is determined by group-based project-deliverable assessments, but this grading scheme apparently increases "test anxiety".

Exploratory Factor Analysis

We conduct exploratory factor analysis to examine the latent variables present in our dataset. The latent variables in our data are composed of combinations of MSLQ scales. We observe the significance of the factor loadings of these scales and their grouping to form the latent variable. Subsequently, these groupings can be compared with the predefined categorization of scales as components by Pintrich. A key aim of this section is to determine the significance of MSLQ scales among students to refine learning and course improvement, along with the need to reduce the time-consuming nature of the MSLQ questionnaire.

The Kaiser-Meyer-Olkin (KMO) test for sampling adequacy is performed on the MSLQ scale-wise data and is found to be adequate at a value of 0.817. The Bartlett test of sphericity is performed and the data are found to be significant (p-value < 0.05). The scales are passed as observed variables for a Principal Axis Factor Analysis in order to determine latent variables present in the data. An oblique rotation, namely *promax*, is utilized. An oblique rotation is chosen for the initial analysis because the factors are presumed to be correlated.

A total of four factors are found above an eigenvalue of 1.00 in our analysis, and a scree plot is created as shown in Figure 7. In Table 4, the factor loadings are presented with a threshold of 0.5, in line with the recommendations of [12]. Furthermore, the table also includes the cumulative factor variances. The four identified latent variables collectively account for 48.9% of the variance within the dataset, with the variable PA0 contributing the largest portion of 19.1%.

The factor of greatest significance (PA0) is a latent variable which measured Intrinsic Motivation, Task Value, Learning Beliefs, Self-Efficacy, and Extrinsic Motivation. This latent variable could be termed: "Motivation and Perceived Ability". This latent variable represents a student's innate desire to perform well in the course, combined with their own perceived ability to succeed in accomplishing this goal. The second factor (PA1) is a latent variable that measures Critical Thinking, Peer Learning, and Help-Seeking. We term this latent variable: "Collaborative Cognition". This latent variable suggests that students who engage deeply in the course, such as exploring beyond the course material, often seek help and collaborate with peers. This seems consistent with the GNG1103 course design, relying as it does on teamwork.

The third factor (PA2) represents Rehearsal and Organization, termed: "Plan & Review". This latent variable implies that students who distill the course material in their own terms, through notes and outlines, are more likely to go back and revise the material again. The final factor (PA3) measures Test Anxiety and Effort Regulation. We term this latent variable as "Anxiety-Driven Effort", representing the ability to study the course material under conditions which require more 'grit' (e.g., when a course is boring or hard or you are feeling lazy, etc.), measured as "test anxiety"-related fear in the course.

A path diagram showing the item (scale) loadings, along with the inter-factor correlations, is

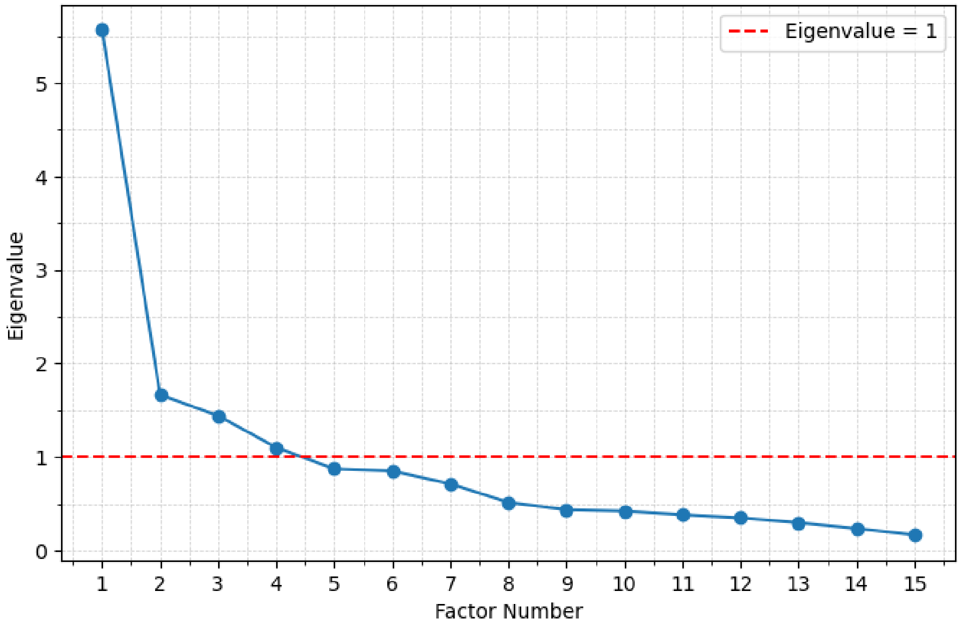


Figure 7: Principal Factor Analysis Scree Plot

Table 4: Principal Factor Loadings

Items	**Latent Variable Loadings**			
	PA0	**PA1**	**PA2**	**PA3**
Intrinsic Motivation	0.797	-	-	-
Learning Beliefs	0.759	-	-	-
Task Value	0.758	-	-	-
Self Efficacy	0.565	-	-	-
Extrinsic Motivation	0.563	-	-	-
Peer Learning	-	0.682	-	-
Critical Thinking	-	0.672	-	-
Help Seeking	-	0.646	-	-
Rehearsal	-	-	0.800	-
Organization	-	-	0.660	-
Test Anxiety	-	-	-	0.531
Effort Regulation	-	-	-	0.521
	Cumulative Factor Variances			
	0.191	0.314	0.430	0.489

shown in Figure 8. Three inter-factor correlations are found above the 0.32 cut-off value as recommended in [13]. The presence of these correlations validates our previously chosen oblique rotation approach. The magnitude of these inter-factor correlations (ranging from 0.439 to 0.608) represent moderate relationships, suggesting distinct but related latent variables [14]. The latent variables PA0 and PA3 show the highest correlation at 0.608, indicating that students with high Motivation & Perceived Ability also exhibit elevated Anxiety-Driven Effort. Notably, the Plan & Review factor was the sole factor lacking correlation with any other factor.

An ongoing challenge in GNG1103, which is a first-year course, is creating a sense of student value for the planning process. Indeed, the current course objective is to teach students basic task management strategies (e.g. ”doing what you say you will do” or ”defining who is responsible for what”) rather than having higher-level project management strategies, which are taught in a follow-on product design course.

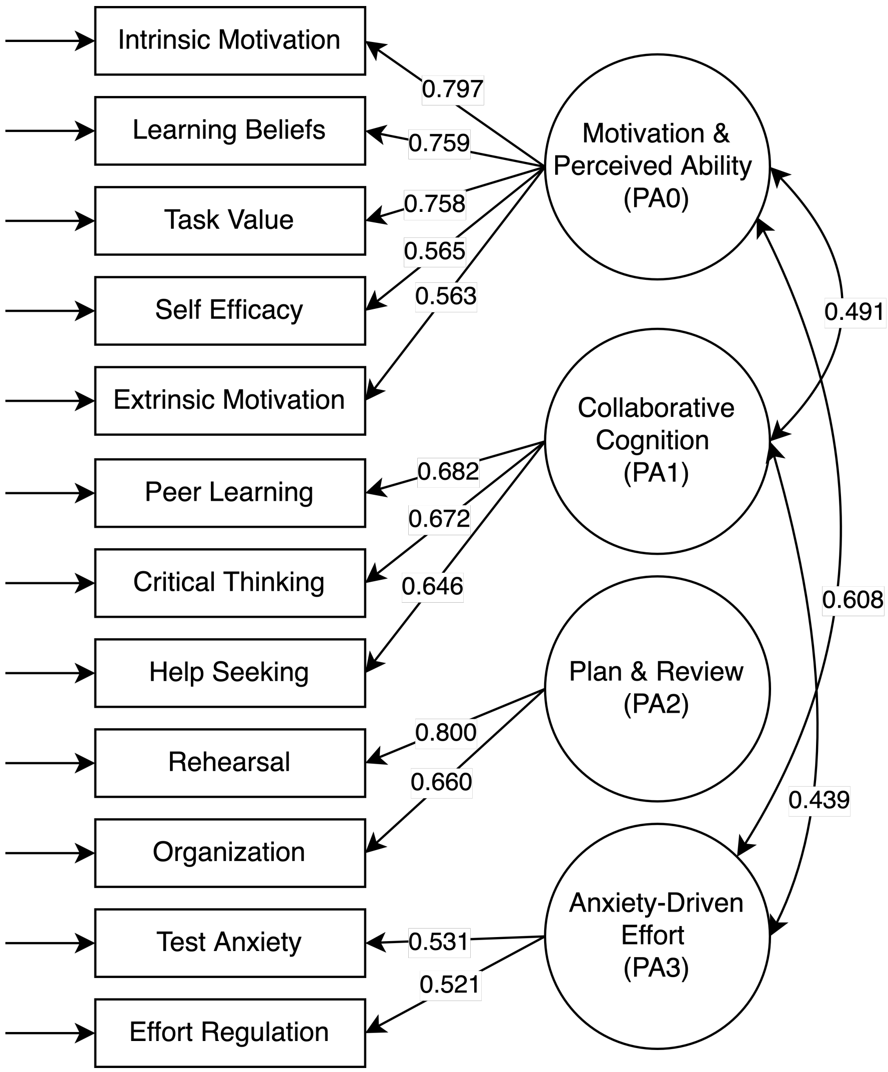


Figure 8: Path diagram depicting item loadings and correlation between latent variables

Among the 15 scales of Pintrich’s Motivated Strategies for Learning Questionnaire (MSLQ), 12 are represented within our latent variables. The scales not included are Time and Study Environment, Meta-cognitive Self-Regulation, and Elaboration. This observation could be attributed to the nature of the questions in the Time and Study Environment scale. Pintrich scales were developed before the advent of "portable digital distraction infrastructure" such as smartphones. His questions focused on the locations where the study activities were conducted.

However, the significance of these locations might have diminished, given the pervasive and universal presence of smartphones and given the option of remote attendance or asynchronous learning models. For example, Question 73, asks if they "attend class regularly". In the context of remote learning, a student may be present for the class yet not fully engaged with the course material, as they might be distracted by other tasks on their computer or smartphone.

Moreover, during the pandemic, many students occupied sub-optimal study environments as numerous households were constrained to share a single office space or forced to re-purpose bedrooms as study areas. Consequently, "attendance in the class" did not necessarily equate to cognitive engagement during the class. Indeed, it might not even have confirmed the presence of the student either. At the University of Ottawa, during the pandemic, it was decided that requesting a student to turn on their web camera, while potentially helping to improve student 'presence', constituted an invasion of privacy (i.e. forcing the student to invite the instructor and/or other students into their bedroom).

The absence of the Metacognitive Self-Regulation scale among the four most significant latent variables implies that reflection skills may not be an essential factor in the course. Since the study was conducted, a series of three reflection assignments have been designed and integrated into the course curriculum. These are designed to encourage students to reflect on what they have learned during the course, in the context of what they already knew beforehand.

Similarly, Pintrich's Elaboration scale comprises questions that are heavily associated with "lecture discussions" and "relating the course material to other courses that the student is taking". Since GNG1103 is experiential and project-based, the focus on lectures is reduced and designed to be synchronized with project activities or to required skills. In addition, the unique experiential nature of the course, in which students work with a client to tackle real-world projects, is unlike the majority of the other engineering courses at uOttawa, not including the design capstone and honours project courses.

Regarding the grouping of scales, among the six scales under the "Motivation" criteria of Pintrich's MSLQ, four scales were identified within our most significant latent variable (PA), "Motivation and Perceived Ability".The Elaboration scale, which was previously discussed, and the Test Anxiety scale were the notable exceptions. The Test Anxiety scale, on the contrary, is associated with the least significant observed latent variable (PA3), namely, "Anxiety-Driven Effort". This result suggests that Test Anxiety may not be a significant factor in the minds of students for this design course. The 5 individually-assessed quizzes, each worth 3%, were distributed evenly throughout the course and the final exam was a summative test after course completion, worth 30%.

Among the nine scales that constitute the "Learning Strategies" criteria of Pintrich's MSLQ, two scales, specifically Metacognitive Self-Regulation and Time and Study Environment, are notably absent from the identified latent variables. The remaining were loaded onto the less significant factors, namely, PA1 to PA3. This observation indicates that among these engineering undergraduate students, the Motivation scales of Pintrich's MSLQ questionnaire hold greater significance compared to the Learning Strategy scales.

However, the scales that do not fall under the Motivation criteria, the Peer Learning scale, had the most significant loading in our factors. This finding is surprising, considering the fact that this scale has the lowest average scores on all scales. This result is also consistent with previous studies.

However, the Peer Learning scale emerges as one of the most influential factors within our observed latent variables. This phenomenon may be attributed to the high emphasis on collaborative group activities within the course curriculum. A similar trend can be observed for the Help-Seeking scale, which had the third lowest average scores across the terms, but was the third most important scale outside of the Motivation criteria.

Conclusions and Recommendations

Overall, the MSLQ scales do not vary significantly across our three modes of instruction, namely: online, HyFlex, and in-person; with the notable exception of self-efficacy. Self-Efficacy for learning and performance in the course dropped significantly during the transition back to the in-person mode of instruction and was correlated with self-regulation. Interestingly, Self-Efficacy values increase when the mode of instruction is kept constant, whether it is remote or in-person learning, as the students become more familiar with that particular mode of instruction. This increase in Self-Efficacy appears to place greater responsibility on the student rather than on the course designer.

Nevertheless, it appears that the "Affective" components, such as "Test Anxiety," warrant more careful consideration by the course designer. Generally, anxiety levels are higher in an engineering design course implementation, which is project-based, like GNG1103. This anxiety level also seems to vary widely between students. It would be interesting to investigate the sources of that variation (e.g., student motivation or ability, etc.) and to compare that with student performance, using assessments by peers or project managers or external judges and clients, that are already part of the course.

Most worryingly, peer learning and help-seeking scores were low in GNG1103, which would seem to be something that course redesign, or perhaps better mentoring, could address. Increasingly, the role of senior student project managers is valued by students, but the recruitment pipeline and "community" of these mentors was also dramatically affected and disrupted by the COVID-19 global pandemic. This pipeline is being recharged, slowly, back to where it was in 2020.

In GNG1103, we use a 'job shadowing' strategy, where senior project managers mentor more junior ones, before being 'appointed'/paid. This process was partially broken by the pandemic, where sidebar or 'overheard" communications all but evaporated, between all students, including between the student mentors. The value of this kind of 'indirect' communication is probably worthy of further study, in the context of the teamwork in the design course and might be worth including in the training that we give to the project managers.

In our exploratory factor analysis, the latent variable “Motivation & Perceived Ability” emerged as the most significant, explaining approximately 20% of the dataset’s variance. This finding indicates that the comprehensive MSLQ questionnaire, with 15 scales comprising 81 items, could be condensed into a five-scale questionnaire with 21 questions to effectively capture our key underlying construct. This could help to shorten the duration of the survey, thereby decreasing the likelihood of user survey fatigue and survey dropout rates.

Moreover, our analysis suggests that the original questions provided by Pintrich for the “Time and Study Environment” scale may not adequately account for the realities of currently prevalent “digital distraction infrastructure”, such as smartphones, particularly within the context of remote learning environments. We suggest that future research should aim to develop more appropriate questions to capture the influence of such distraction infrastructure.

Further studies should be performed, with a prolonged online mode of instruction, to observe if the students’ self-efficacy becomes comparable with that of the assumed (2024-level) in-person mode, on a longer-term basis. In general, it might be informative to compare or correlate these scales with overall performance in the course (e.g., using individual assessments like the final exam, or the peer-based assessment of personal group contribution. Equally, the overall final grade could be used, although this is highly dependent on the project design deliverable assessments). However, none of these were within the bounds of the ethical permissions that were obtained for our own study.

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