Emulating Real World SE Practices in Computer Science Classrooms

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***Abstract*—This research-to-practice paper describes the analysis of the application of Project Based Learning (PjBL) using industry standard tools and practices (ISTP) in Computer Science / Software Engineering courses and investigates the students' engagement and learning effectiveness. PjBL is an instructional strategy that helps students to learn and acquire skills by solving real world problems. Industry standard tools (e.g., GitHub, Jenkins etc.) and industry standard practices (e.g., Agile method based practices) can be used to imitate the real-world software engineering activities in a PjBL classroom. Many scholars have studied the impact of PjBL on student performance, retention, motivation, and engagement. While existing studies make contributions, there exists a knowledge gap on the interplay between industry standard tools and practices (IST&P) and PjBL. Moreover, the effectiveness of IST&P in supporting students' performance, motivation and engagement in PjBL have not been well studied and are largely unknown. Consequently, instructors are hardly intentional about the integration of IST&P to PjBL, this makes it more difficult for students to learn how to use IST&P in PjBL leading them to graduate without being well prepared for the real-world software engineering industries. To fill this gap and contribute to knowledge, this paper investigates the effectiveness of IST&P in the learning effectiveness, and the engagement of the students in Software Engineering courses. We carried out an empirical study among 68 students in a mid-sized classroom of a small university in Northern Pennsylvania, United States. We collect data using the Reduced Instructional Materials Motivation (RIMMS) survey as one of our instruments to evaluate students' engagement, and the Topical Content Test (TCT) based on the revised Bloom's taxonomy to evaluate the learning effectiveness of the proposed PjBL process. Our results show that PjBL using IST&P has a significantly positive impact on students' engagement. It also significantly correlates with the learning effectiveness in project based SE courses. We also noticed that although this process leads students to perform highest in Analysis and Evaluation levels of Bloom's taxonomy, students with better performance in Application level performs better in the Create level.**

***Index Terms*—Computer Science, Instructional Design, Bloom's taxonomy, Classroom, Students Engagement, Learning Effectiveness, Project Based Learning.**

I. Introduction

The gap between software engineering students and professionals has significant impact on newly graduate Software Engineering (SE) or Computer Science (CS) students [1] [2] [3] When shifting to real world Software Development and Engineering from school projects, CS graduates often face difficulties adjusting to new environment unless they have a substantial amount of internship experience. In the undergraduate or graduate schools, SE courses are intended to teach the students how to develop, manage, and maintain software projects. Although, there are SE courses that help them develop their understanding of how software development and engineering processes work in the industries, applying the techniques in a professional setup and the familiarity with the required tools in the industries is always ignored.

In the CS/SE course-projects students are given a project and asked to implement a complete software system. The idea behind doing a project is to give the students an experience of developing a complete software project by collaborating with stakeholders and following a formal development methods including project planning, requirements analysis, designing, implementation, quality assurance, testing, and deployment. Students get the opportunity to learn how to write documentations, test cases, and to validate their work with stakeholders. Such course projects provide students with the experience of team-work, testing, quality assurance, development life-cycle, documentation, writing technical reports, presenting the work, and possibly other formalities from business and SE perspective.

The attempt of IST&P integration is laudable, however there remains the question which is, how the effort at integration supports student engagement and learning.

This study has been conducted among 68 students in three SE courses: i) Software Engineering ii) Software Testing iii) Software Maintenance. These SE courses that are fully aligned with Agile development practices which is our requirement for this study to implicate IST&P. The students where undergraduate majoring in computer science or software engineering or both. It was a mix of 25% sophomore, 20% junior, 30% senior, and 25% junior students. There were no freshmen students in these classes. There were 20 female and 48 male students. A total of 5 African international, 8 African American, 4 Indian, 3 Chinese, 6 Mexican, 7 Middle-Eastern, 9 Eastern-European, and 26 local American students were part of this process.

A. Tools

We use the tools commonly used in most of the software development industries and widely popular among the practitioners. For project management and issue tracking we use **Atlassian Jira**, **GitHub** for source code maintenance and version control, **Jenkins** for building the project code and integrate unit tests in a continuous integration mechanism.

Atlassian Jira: A wide variety of project management tools have evolved to this modern day [4] facilitating the control over Agile development process. Atlassian Jira [5] is one of the leading software project management tools for decades. Jira is able to manage small as well as extremely large software projects [6] with its useful features to drive an Agile scrum-based software development process.

GitHub: GitHub is a widely popular community of developers. One of the many products and services that GitHub offers is the repository for source code version control. In this study we let the students use the repository service where they share their project's source code and practice collaborative development using the branching and other repository-features of GitHub.

Planning Poker: To estimate the user stories in Jira many software development teams prefer to use web based tools that help estimation by playing games such as planning-poker [7], pointing poker [8] etc. We are using planning-poker because of its simplicity and popularity which allows estimation using Fibonacci series, custom-fibonacci series, T-Shirt size, etc.

Jenkins: While development is in progress, a working copy of the software has to be ready at all times as part of the Agile methodologies [9]. For that we used Jenkins to continuously build the project. Jenkins is vastly popular [10] and stable over the past few decades.

B. Practices

Agile development practice is gaining popularity rigorously over more than a decade [11]. It is the most popular approach of developing client focused software applications. Hence, we are following the Agile development method and its best practices to run the projects.

Bi-Weekly Sprint: Bi-weekly sprint is a common practice in Agile development practice which implies the development iterations [12]

Daily Scrum: It is a daily session with all the developers and team lead that reviews what has been accomplished, as of now and what are the goals next, and any impediments. It is one of the keystone practices in the Agile development process [13] [14]. It drives the sprint, keeps the developers engaged and up to date with the sprint progress.

Sprint Retrospective: In a sprint based development where scrum focuses on the progress, retrospective session is a vital session for the sprint where the criticism of the past sprint addresses the points of improvement which is one of the Agile principles [15].

C. Research Questions

To achieve the goals of this study we wanted to answer the following two questions.

RQ1: ***Do industry standard tools and practices contribute to students' engagements, and satisfaction in project based learning?***
We used RIMMS [16] survey as an instrument of measuring the students' engagement. To answer this research question we individually analyzed students' responses for each element of ARCS [16] model which is the foundation of the RIMMS questionnaire.

RQ2: ***How effective are the industry tools and practices to students' learning?***
We want to know whether students effectively learn the subject matter by going through this PjBL process. To answer this question we used pre-test and post-test IST&P surveys and observed the correlation of the improvement with the performance in Topical Contest Test.

RQ3: ***Which Bloom's Taxonomy Levels are Highly Impacted by the PjBL using IST&P?***
There are six levels in Bloom's taxonomy [17]. This question aims to know if our approach of using IST&P in PjBL does correlate with all or some of the Bloom's levels significantly.

II. Related Works

Many institutions even leverage common industry-standard tools [18] [19] and practices, for the purpose of connecting students to Industry Standard Tools and Practices (IST&P). Grabowski et. al. [18] conducted a similar study to emulate the corporate professional standard software development among six software engineering courses' student groups. Unlike Grabowski, we are more interested in assessing the learning effectiveness and students' engagement through the use of IST&P instead of just business experience.

Novak et al. [20] studied the effects of an instructional gaming characteristic on learning effectiveness, efficiency, and engagement. In this study authors investigated how effective it is to use gaming characters in undergraduate/graduate studies. They also measured the teaching efficiency and how students' engagement improves through the process. They used the "Storyline" as game-design element for teaching courses while we use IST&P as the game design elements.

Fisher et al. [6] analyzed the utilization of Atlassian Jira (project management tool) for managing large-scale software development. The insights of the Jira project management tool allow us to apply on large and scattered student projects as well.

Besides tools, techniques are also incorporated with Software Engineering course projects in the literature. Rodriguez et al. [21] applied virtual scrum in students' capstone project. Based on student feedback they understood that virtual scrum is a viable and effective tool to implement the different elements in a Scrum team room and to perform activities throughout the Scrum process.

The teaching of Software Engineering poses significant challenges, particularly when confronted with large student cohorts and diverse backgrounds, workloads, and availability for in-person learning. These challenges are further intensified when the objective is not only to impart essential theoretical knowledge but also to enhance students' employability by emphasizing industry-oriented projects.

Another highly similar study was conducted by Arantes et al. [22] where they present the outcomes derived from the implementation and customization of an agile software development approach in a course called "Interdisciplinary Software Project IV" within the Bachelor's program in Software Engineering at the Pontifical Catholic University of Minas Gerais. This approach was employed over a span of two years and encompassed a total of twenty projects.

III. Methodology

IST&P encompasses a set of tools and practices widely employed in various industries. In this study, we utilized Atlassian Jira, GitHub, and Jenkins as the tools for project management, source version control, code build and test integration. Additionally, we employed Planning Poker as a tool to assist sprint planning and story estimation as part of the Agile practices. Figure 1 provides a concise overview of the methodology.

We began the process by providing instructions to the students about the project setup, objective, method, and the tools and practices they are going to use. Instructions were given on the first day of the semester. Then we did let the students take the "Pretest Survey" on the next class session. The pretest survey score helped us to understand their initial level of their experience, and their familiarity with the tools and practices to be used in the project.

Once the pretest survey is done, we continue regular class lectures specific to the course where students learn the original course content. The course projects began immediately after the mid-term exam as shown in Figure 1. The course projects were designed focused on the course topic and learning objectives. Students had their freedom to decide what project they wanted to work on. However, they needed instructors' approval to make sure the projects selected by the students were ideal for that course satisfying the following criteria:

1) Project has to be specific to the course topic
2) Project must allows application of Agile development practices
3) Project must enforces students to learn course related subject matters
4) Project must be doable within 8 weeks

The projects were planned with four bi-weekly sprints for an overall duration of 8 weeks. Once the projects were completed, during the last week of the semester, students were given a "Topical Contest Test (TCT)", and a "Post-Test Survey". The TCT is more like a final exam containing mostly multiple choice questions for Remember, Understand, Apply, Analyze, and Evaluate levels, and we used narrative questions for the Create level of the revised Bloom's Taxonomy [17].

The post-test survey contains the similar questions as pre-test survey so that we can compare the improvement on understanding and familiarity with the tools and practices.

The Bloom's taxonomy based TCT contained seven questions from "Remember", four questions from "Understand", six questions from "Apply", three questions from "Analyze", ten questions from "Evaluate" and three questions from "Create" level of Bloom's taxonomy.

Students' Engagement: To analyze students engagement we used the RIMMS survey scores and the scores obtained from the TCT. We anticipate that one or more of the ARCS model elements [16] from the RIMMS

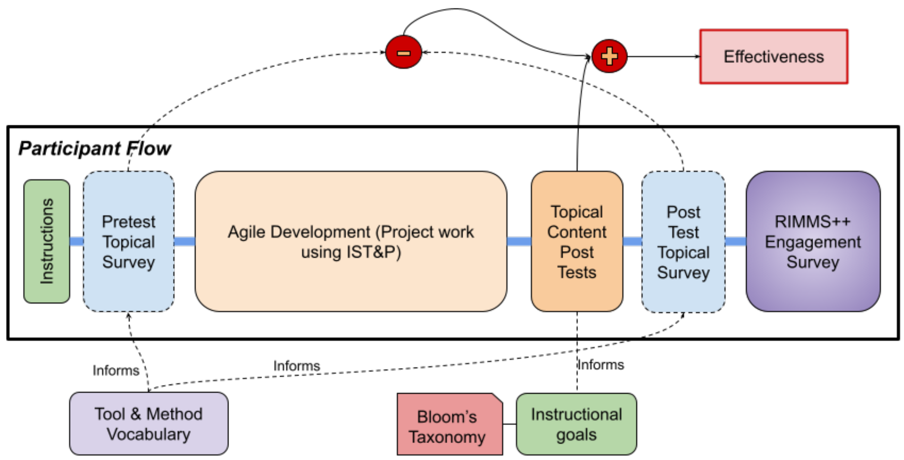

Figure 1: Methodology of the study.

engagement survey will have a positive correlation with the TCT performance.

Here the null hypothesis is:
H_0^{se}***: Means of observations grouped by the ARCS model elements have no correlation with the means of observations grouped by TCT***

Learning Effectiveness: To analyze the learning effectiveness we use the topical content test scores and the knowledge gained in IST&P. The data collected from the difference between pre and post-test surveys. We anticipate that the difference between pretest and post-test survey (δ) has an impact on the students' performance in TCT. In simple words, if a student had gained knowledge on the industry standard tools and practices, then we assumed that student would have done better in the topical content test (TCT).

Here the null hypothesis is:
H_0^{le}***: Means of observations grouped by the difference between pre and post-test scores have no correlation with the means of observations grouped by TCT***

Our approach involves an empirical investigation on students' experiences and outcomes. As depicted in Figure 1, the process begins with an IST&P survey focusing on students' familiarity and ability to use the selected IST&Ps. Followed by a 8-week long project development and finally, at the end of the projects a RIMMS [16] survey was employed to analyze student engagement and a topical content test to assess the contextual learning outcome. Figure 1 represents our methodology at a glance.

A. *RIMMS++:*

As indicated in Figure 1, the learning effectiveness was observed through the change in IST&P surveys (pretest and post-test) and in performance on TCT. Students' Engagement was be observed through the RIMMS instrument and the detailed responses according to the ARCS elements. At the center of this approach is the application of the RIMMS approach in assessing student engagement. While the RIMMS work developed a series of validated questions useful for assessing Attention, Relevance, Confidence and Satisfaction (ARCS) [23]. The RIMMS instrument was built around twelve questions, with three questions in each of the ARCS categories.

For our use, these questions required modification. RIMMS centred on ARCS assessment of student engagement specific to instructional message design [16], our interest is in assessing engagement with a set of IST&Ps. Our approach was to parameterize the RIMMS questions, for the purpose of shifting the target from "user instructions" to student engagement with a particular IST&P oriented setup, while at the same time shifting the context from "using a telephone" to the team project. Table I depicts this transformation, illustrating the original RIMMS question and the resulting RIMMS++ question. The third column contains the original RIMMS questions and the last column shows the transformed questions particularly for our study.

While we were transforming the original RIMMS questions to our RIMMS++, we observed that the original RIMMS included two very similar "Satisfaction" questions: **R10** and **R11** (See Table I). For our experiment, we replaced the original R11 and R12 in our RIMMS++ with the new "R11 rewrite" and "R12 rewrite" questions following the ARCS principle.

IV. Data

We collected the data from the four sources pretest survey, post-test survey, RIMMS++ motivational survey, and Topical Content Test (TCT). The students where undergraduate majoring in computer science or software engineering or both. It was a mix of junior and sophomore students.

The IST&P survey pretest survey checks the initial knowledge of the students on the instruments used in the PjBL process. As shown in Figure 2 we divided the students into two groups (GroupA and GroupB) based on their prior knowledge on the industry standard tools and practices. GroupA has the students who had pretest survey score below 40% and GroupB has the students who had pretest sruvey score above that.

The median core of the post-test survey is higher for GroupB. This is because they already had prior IST&P knowledge. However, the difference between pre and post test is higher in GroupA compared to GroupB. Which indicates that students

Table I: RIMMS++ : Transformed Questions from Original RIMMS 2015

RIMMS Q	ARCS Principles	Original RIMMS Question [16]	RIMMS++ Question
R01	Attention: Perceptual Arousal	The quality of the ⟨text⟩ helped to hold my attention (11A03)	The quality of the **Industry Standard Tools & Practices** helped to hold my attention
R02	Attention: Inquiry Arousal	The way the ⟨information⟩ is arranged on the pages helped keep my attention (17A06)	The way the **Industry Standard Tools & Practices** are arranged in the development process helped keep my attention
R03	Attention: Variability	The variety of ⟨reading passages, exercises, illustrations⟩, etc, helped keep my attention on the ⟨user instructions⟩ (28A10)	The variety of **activities, tools, planning and other practices**, etc, helped keep my attention on the **Industry Standard Tools & Practices**
R04	Relevance: Familiarity	It is clear to me how the content of these ⟨user instructions⟩ is related to things I already know (06R01)	It is clear to me how the content of these **Industry Standard Tools & Practices** is related to things I already know
R05	Relevance: Matching Motives	The content and style of ⟨writing⟩ in these ⟨user instructions⟩ convey the impression that being able to work with the ⟨telephone⟩ is worth it (23R06)	The content and style of working in these **Industry Standard Tools & Practices** convey the impression that being able to work with the **Course Project** is worth it
R06	Relevance: Goal Orientation	The content of these ⟨user instructions⟩ will be useful to me (33R09)	The content of these **Industry Standard Tools & Practices** will be useful to me
R07	Confidence: Learning Requirements	As I worked with these ⟨user instructions⟩, I was confident that I could learn how to work well with the ⟨telephone⟩ (13C05)	As I worked with these **Industry Standard Tools & Practices**, I was confident that I could learn how to work well with the **Course Project**
R08	Confidence: Success Opportunities	After working with these ⟨user instructions⟩ for a while, I was confident that I would be able to complete exercises with the ⟨telephone⟩ (25C07)	After working with the **Industry Standard Tools & Practices** for a while, I was confident that I would be able to complete the **Course Project**
R09	Confidence: Personal Control	The good organization of the ¡content¿ helped me be confident that I would learn to work with the ⟨telephone⟩ (35C09)	The good organization of the **industry standard tool or practice** helped me be confident that I would learn to work in the **Course Project**
R10	Satisfaction: Intrinsic Reinforcement	I enjoyed working with these ⟨user instructions⟩ so much that I was stimulated to keep on working (14S02)	I enjoyed working with these **Industry Standard Tools & Practices** so much that I was stimulated to keep on working ⟨on the **course project**⟩
R11	Satisfaction: Intrinsic Reinforcement	I really enjoyed working with these ⟨user instructions⟩	I really enjoyed working with this **industry standard tool or practice**
R12	Satisfaction: Equity	It was a pleasure to work with such well-designed ⟨user instructions⟩	It was a pleasure to experience working with this well-designed **industry standard tool or practice**
R11 rewrite	Satisfaction: Extrinsic Reinforcement	⟨Completing the exercises⟩ gave me a satisfying feeling of accomplishment	**Working with this industry standard tool or practice** gave me a satisfying feeling of accomplishment
R12 rewrite	Satisfaction: Equity	The design of the ⟨user instructions⟩ made for a satisfying learning experience. (36S06)	The integration of **working with this industry standard tool or practice** into my course project made for a satisfying learning experience

in GroupA had greater knowledge gain compared to GroupB students.

The RIMMS++ survey has three questions from each element of ARCS (Attention, Relevance, Confidence, Satisfaction) model with a total of 12 questions. The median score of the Attention, Relevance, Confidence, and Satisfaction was 7.75, 7.85, 8.0, and 7.9 as shown in Figure 3. The overall median RIMMS score was pretty similar for all the students.

Finally, we collected the TCT scores from the topical content test results. It was an exam on the subject topic was graded by the instructors to assess how much topical knowledge was gained by the student. In median case students earned 156.0 out of 170.0 in the TCT exam which is equivalent to 86.67%.

V. Analysis

A. Students' Engagement

We conducted assessment between ARCS models of the RIMMS survey and the TCT scores of the students. We used Pearson's correlation coefficient (r) due to its simplicity, interpret ability, and wide application across many fields. Figure 4 shows the correlation between TCT and the individual ARCS elements (Attention, Relevance, Confidence, and Satisfaction).

1) Attention and TCT

The correlation test between attention and TCT had a t-value of 12.52 with 66 degrees of freedom, resulting in a low p-value of $4.21e^{-19}$. Our null hypothesis was: *There is no correlation between TCT and Attention Average*. The small p-value allowed us to reject the null hypothesis, indicating that the true correlation between the variables is not equal to zero. The estimate of the correlation coefficient was 0.84. This value signifies the strength and direction of the linear relationship between TCT and Attention Avg. A correlation coefficient close to 1 indicates a strong positive linear relationship, suggesting that as one variable increases, the other tends to increase proportionally. In this case, the positive sign of the correlation coefficient (0.84) affirms a robust positive correlation between Attention and TCT score.

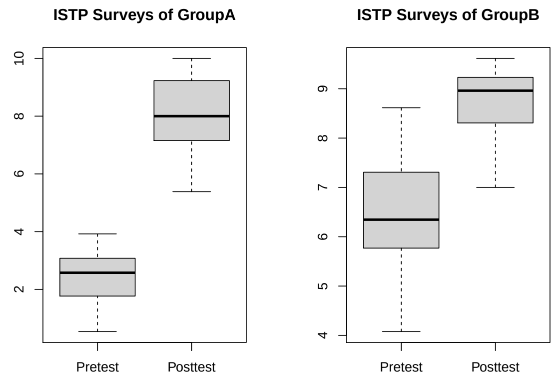

Figure 2: IST&P Surveys (Pre and Post) in GroupA and GroupB

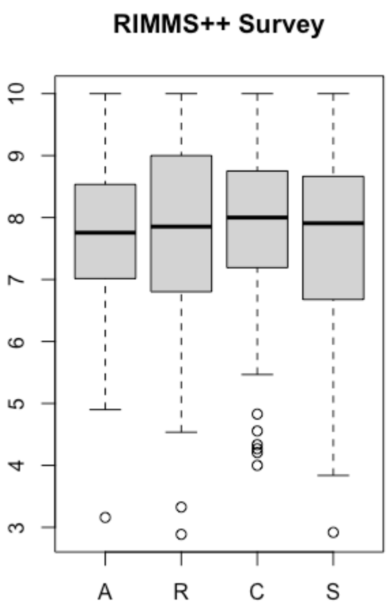

Figure 3: Boxplots for each element of ARCS model in RIMMS++ Survey

2) Relevance and TCT

In the exploration of the relationship between TCT and Relevance Average, through Pearson's correlation coefficient, the obtained results reveal a statistically significant association. The analysis yielded a t-value of 5.72, with 66 degrees of freedom, resulting in an extremely low p-value of $2.73e^{-07}$. This notably low p-value leads to the rejection of the null hypothesis, suggesting that the true correlation between the variables is not equal to zero. The null hypothesis posited that there is no correlation between TCT and Relevance Average. Conversely, the alternative hypothesis proposed that a correlation does exist. The statistical evidence overwhelmingly supports the alternative hypothesis, indicating a robust correlation between the Relevance and TCT. The correlation coefficient is 0.5762. This coefficient denotes the strength and direction of the linear relationship between TCT and Relevance Average.

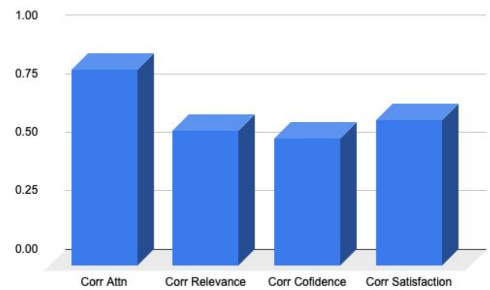

Figure 4: Correlation between TCT and the individual items in ARCS model of RIMMS survey

3) Confidence and TCT

The statistical analysis shows a significant correlation between TCT and Confidence Average with a p-value of $1.84e^{-06}$ for the t-value of 5.2352 with 66 degrees of freedom. This low p-value strongly rejects the null hypothesis, indicating a non-zero correlation between variables. This statistic supports the alternative hypothesis of a non-zero correlation. This indicates a significant correlation between Confidence and TCT score.

A moderate positive linear relationship is indicated by a correlation correlation of 5.24.

A low p-value and confidence interval excluding zero support the null hypothesis rejection, demonstrating the relationship's robustness. The positive correlation coefficient of 5.24 emphasizes this association's strength and direction. These findings help explain the relationship between these variables and demonstrate how statistical methods can be used to gain insights from data.

4) Satisfaction and TCT

Finally for satisfaction, we observe a strong correlation between TCT and Satisfaction Average. With 66 degrees of freedom, a t-value of 6.4374 and a very low p-value of $1.6e{-}08$ it rejects the null hypothesis, indicating a non-zero correlation between variables. A positive correlation of 0.62 suggests a relatively strong positive linear relationship.

5) Overall ARCS Average and TCT

The Pearson correlation coefficient between TCT and and the overall average of the ARCS from RIMMS survey is 0.6762 with 66 degrees of freedom and p-value of $2.48e^{-10}$, indicating a strong positive linear relationship between them.

This correlation suggests that the more the students are attentive, found the process relevant, felt confident, and satisfied, as the Topical Content Test performance increases.

B. Learning Effectiveness

We further analyze the learning effectiveness of students using the IST&P surveys and the TCT performance. This analysis compares the TCT performances of two groups of students. Students who initially had little knowledge on the IST&P instruments (with a score below 4.0 in the pre-test survey) belong to Group-A. On the other hand students who already had better knowledge on IST&P instruments (with scores higher than 4.0 in pre-test survey) belong to Group-B. Figure 5 and Figure 6 are presenting the distribution of the data samples in group A and B respectively. The goal is to reveal patterns of post-test score improvement for these cohorts and draw conclusions about how starting performance affects academic development.

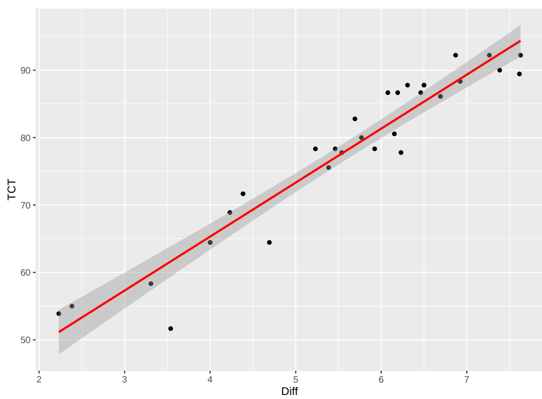

Figure 5: Pre-Post Diff for Group-A (low pre-test score)

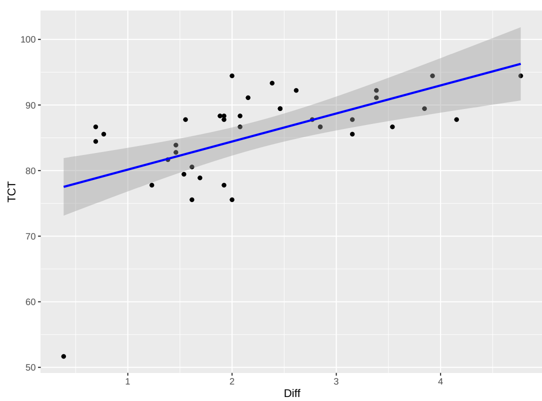

Figure 6: Pre-Post Diff for Group-B (high pre-test score)

The idea is to find a correlation between the knowledge-gain δ on the IST&P instruments and the TCT performance. The knowledge gain is measured from the difference between pretest and post-test surveys. Knowledge gain in Group-A is denoted by δ_A and knowledge gain in Group-B is denoted by δ_B.

In Figure 7 we see that δ_A shows a very strong positive correlation of 0.96 with the TCT performance with a highly significant p-value of 7.892e-05. Group-B also shows a positive correlation with a p-value of 0.004 indicating a moderate association between δ_B and TCT performance of the students who already had prior knowledge on the IST&P instruments.

VI. Results & Discussion

We have analyzed students' engagement and learning effectiveness through the PjBL using IST&P in SE courses for computer science undergraduate students. Our objective was to investigate if the process engages the students in process (RQ1) and also if the students learn the subject matter or topical content through the project based learning using IST&P (RQ2). We stated two null hypothesis in the methodology section, H_0^{se} for students' engagement, and H_0^{le} for learning effectiveness. H_0^{se} states that the means of observations in each ARCS elements have no relationship with the means of TCT scores. A paired t-test shows that the t value is less than zero with a $p - value < 2.2e^{-16}$ for each of the ARCS elements. Therefore, we can reject the null hypothesis H_0^{se} which allows us to conclude with an alternative hypothesis "*Means of observations grouped by the ARCS model elements have high correlation with the means of observations grouped by TCT*". Furthermore, in the analysis section we showed that each of the ARCS elements have positive correlations with the TCT performance of the students. Particularly, attention has the strongest correlation proving that if a student was attentive to the PjBL with ISt&P process, then that student had a higher score in the topical content test. Satisfaction has the second highest correlation (Figure 4) meaning, if a student was satisfied with the project setup, then that student had eventually performed well.

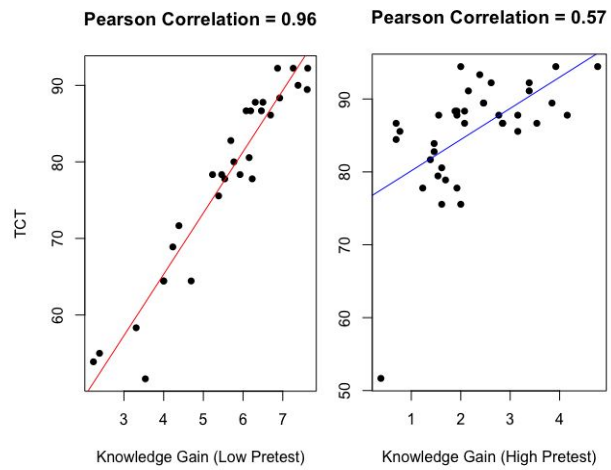

Figure 7: Correlation between knowledge-gain in low pretest (Group-A) and high pretest (Group-B) groups

Answer to RQ1: Industry standard tools and practices (IST&P) con highly tribute to students' engagements, and satisfaction in project based learning.

Students who had lower score (less than 4.0) in the pretest survey and the ultimate knowledge gain on the IST&P instruments were high performed better in TCT compared to the students who had lower knowledge gain having an existing higher knowledge in the IST&P instruments. This indicates that students were able to utilize the IST&P based process efficiently, and learned through the process being attentive and performing well. We assume that students who didn't have a lot of knowledge on IST&P at the beginning and wanted to learn these tools and practices through the course project had a curiosity and hunger of learning. This curiosity and hunger of learning helped them to be more attentive and satisfied and at the end performing well in TCT. Thus, this analysis also validates the answer to RQ1.

Answer to RQ2: The industry tools and practices are highly effective for students' learning.

We further analyzed which Bloom's levels are more affected

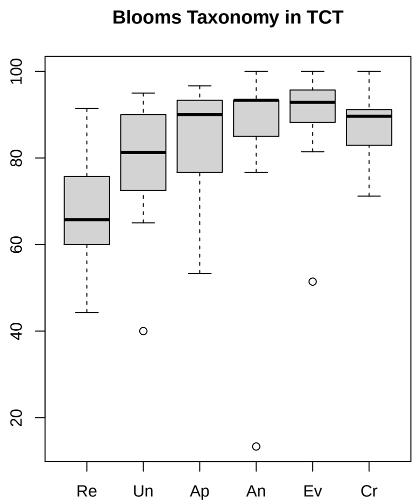

Figure 8: Student's performance in TCT per Bloom's taxonomy level

during the learning process through the PjBL using IST&P. We observed that students performed best at the Analysis, and Evaluation levels. In median case students scored 93.33%, and 92.85% in Analysis, and Evaluation categories respectively. from the questions grouped in Created level in the TCT. Students also performed very well in Apply level with the median scores of 90.10% as we can see in Figure 8. The median Understand score was 81.25%, and for Remember it was 65.71%.

The relatively lower score in Remember level (66.71%) clearly indicates that the students' learning was more driven by the application, analysis, and creativity rather than memorizing. This was anticipated in a project based learning environment especially using industry standard tools and practices.

We performed a one-way ANOVA on the percentages of the students' scores in each group of Bloom's levels. Our null hypothesis was: *"There is no significant difference among the Bloom's levels"*. The F-Statistic was 8.36 with a P-Value of 1.94e-08. Since the p-value (1.94e-08) is much smaller than the significance level (0.05), we reject the null hypothesis. This suggests that there are significant differences among the Bloom's levels in TCT.

We further performed a Pearson's correlation test between the δ_A in GroupA and each Bloom's level, and δ_B in GroupB and each Bloom's level in TCT. Our null hypothesis was *"There is no correlation between δ and Bloom's levels in TCT."*

Table II shows the correlation coefficients between $\delta_A and \delta_B$ and each Bloom's level score in TCT. We see Apply, Analyze, Evaluate, and Create levels have highly significant correlations with the IST&P knowledge gained in both GroupA and GroupB and certainly we reject the null hypothesis for Apply, Analyze, Evaluate, and Create.

We further investigated the correlations among the individual Bloom's levels and found that Apply level has a strong correlation of 0.84 with Create level indicating the IST&P positively affects applicability and the students have higher applicability also has higher creativity.

Table II: T-Test scores between δ in Group A and B and Bloom's Levels

Knowledge Gain δ	Bloom's Levels	Coefficient	p-Value
δ_A	Remember (Re)	0.24	0.004
	Understand (Un)	0.41	0.0001
	Apply (Ap)	0.78	$2.01e^{-16}$
	Analyze (An)	0.81	$4.11e^{-19}$
	Evaluate (Ev)	0.83	$7.01e^{-17}$
	Create (Cr)	0.91	$1.56e^{-9}$
δ_B	Remember (Re)	0.31	0.04
	Understand (Un)	0.35	$1.01e^{-4}$
	Apply (Ap)	0.52	$6.77e^{-9}$
	Analyze (An)	0.64	$2.55e^{-12}$
	Evaluate (Ev)	0.73	$8.03e^{-11}$
	Create (Cr)	0.81	$4.67e^{-19}$

This answers our third research question as below.

Answer to RQ3: There is a strong significant correlation between IST&P knowledge gain and the top four levels of Bloom's taxonomy.

VII. Conclusion

In this study students get the opportunity to do their course project through an industry standard software development process following Agile methods including daily scrum, sprint planning, sprint retrospective. The IST&P in PjBL helps students stay engaged in the classroom and the course project. It also allows students learn the course contents effectively, and positively affects the top four Bloom's taxonomy levels. We used the ARCS model based RIMMS engagement survey inspired by previous studies and update the RIMMS model to RIMMS++ adapting with the IST&P based PjBL. We believe this contribution would further facilitate future studies to experiment PjBL using industry standard tools and practices. We found that students were highly attentive and satisfied with the emulation of real world SE practices. More importantly the students who didn't have prior knowledge on the tools and practices stayed more engaged and attentive and eventually learned more about the course subject matters through the process.

Future studies will explore deeper into the effectiveness of individual IST&P tools on a wider variety of classrooms. We will compare the effectiveness and engagements between undergraduate and graduate students. We will also investigate and measure how IST&P can reduce the gap between the university curricula and the industry demands from Software Engineering fresh graduates.

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