Improving Technology Student Critical Thinking Skills Through Trained Writing Tutor Interactions

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Abstract

Senior projects are typically funded by industrial sponsors who pose a problem for students to solve. All too often, students concentrate on the application of engineering concepts before accurately identifying the source of the problem. The result is that the students' solutions can an exacerbate rather than solve the real problem. This paper discusses the results of an investigation of an intervention with the potential to improve students' identification of the optimal solution to the problems posed by sponsors.

The intervention represents an extension of research funded by an NSF IUSE: EHR Multi-institutional grant to improve writing support for engineering students on their technical documents through the use of peer writing tutors from non-technical backgrounds, collaboratively trained by engineering faculty and writing tutor supervisors. The project, Writing Assignment Tutor Training in STEM (WATTS), has been conducted in three universities over three years and has demonstrated statistically significant improvement in STEM undergraduate writing after students received tutoring from WATTS-trained tutors.

At the beginning of a WATTS tutoring session, students provide an elevator speech to the tutors, summarizing the content of their reports. The researchers hypothesize that the tutors, as a general audience, are more likely to see the problem from a broader perspective. Also, students must explain the reasoning behind their choice of a solution, both of which have the potential to enable the students to improve their critical thinking skills in their discipline. By explaining their projects, students have the opportunity to identify gaps in their own understanding [1]. WATTS training materials have been adapted to include this aspect of the content of students' reports. This study was conducted in the first semester of a two-semester Mechanical Engineering Technology (MET) senior design course. The results and analysis are included in this paper.

Introduction

This study is a continuation of ongoing work investigating the efficacy of using the Writing Assignment Tutor Training in STEM (WATTS) methodology. The WATTS system uses a train-the-tutor approach to improve the quality of undergraduate writing; this methodology showed significant improvements in writing quality for the participating students across several engineering majors [2]. Other works on this same project include [3], [4] and [5]. This follow-up study investigated another potential benefit of the WATTS initiative—improvement of critical thinking skills as part of the peer tutoring process. Prior to this project, data collection and analysis focused primarily on assessing WATTS' impact on STEM student writing. Publications regarding those are outcomes are readily accessible.

WATTS' Pedagogical Framework

The principles of *knowledge transfer* [6] provide the structure for the tutor training. The first is familiarizing the tutors with the unknown domain, and the second is providing examples

accompanied with rules. These are accomplished by the instructors, who give the tutors a layman's explanation of the assignment, its formatting conventions, and uses illustrative examples of lab reports of varying quality.

The third principle, showing learners how problems resemble each other, and the fourth, directing learners' attention to the underlying goal structure of comparable problems are accomplished by the tutor supervisors. Supervisors point out parallels between the feedback the tutors give on research papers written in first-year composition courses (which usually provides the bulk of their tutoring experience) and feedback they would give on the examples of the lab reports the instructor uses during the training. Both are based on the same rhetorical principles that underlie a well-written research paper or lab report.

The final principle, fostering learning that takes place in a social context (e.g., reciprocal teaching), whereby justifications, principles, and explanations are socially fostered, generated, and contrasted is accomplished both in the training and in the tutoring session. The training is a collaborative group environment. Tutors are encouraged to ask questions, clarify expectations, and make contributions to the discussion based on their tutoring experience. WATTS training provides generalist tutors with the background knowledge and self-efficacy to engage STEM students in meaningful conversations about their reports and reinforce the students' understanding and application of rhetorical principles.

Given that the tutors' focus is on writing and students' ability to express their ideas in an understandable way, only two of the nine Universal Intellectual Standards of the Paul-Elder Critical Thinking Framework [7] apply to the writing tutoring session. They are:

1) Clarity:
   Could you elaborate further? Could you give me an example? Could you illustrate what you mean?
2) Precision:
   Could you be more specific? Could you give me more details? Could you be more exact?

Methodology

The American Association of Colleges and Universities' (AAC&U) Valid Assessment of Learning in Undergraduate Education (VALUE) Rubric for Critical Thinking was used for assessment of tutor qualitative feedback and student reports. There are four rating levels, with 1 being the lowest and 4 being the highest. There are five categories of assessment: 1) Explanation of Issues, 2) Evidence, 3) Influence of Context and Assumptions, 4) Student's Position, and 5) Conclusions and Related Outcomes. Given that tutors were providing feedback on students' ability to present their ideas clearly in their reports, the Explanation of Issues category was used.

Tutors completed an additional quantitative form that provided data regarding the level of student engagement during the session.

Project description

The MET writing assignment tutored was the analysis report, which is a component of a senior-level capstone design sequence. The students work on design projects, either as a team, or individually as part of an internship experience. Students must select a component of their design and analyze it by applying content learned earlier in the program. Internship students are allowed to analyze any component of their design, while students assigned to teams are expected to coordinate with other team members and analyze a unique component of their team's design to avoid duplication of effort between team members.

Students are expected to introduce their design project in sufficient detail to allow a technical reader to understand the report. They are then expected to model the component of their design as a textbook case for which an analytic or closed-form solution exists. For example, a bracket holding a suspended weight a known distance from a support can be modeled as a cantilever beam; while a hook connected to the same bracket and supporting the suspended load can be modeled as a curved beam in bending.

After selecting the appropriate model, the students analyze the component for various critical parameters (strength, stiffness, fatigue life, etc.), report the results, and draw a conclusion about the suitability of the design. Students may choose to verify their results (which are understood to be approximate) with numerical methods if desired, but this is not part of the assignment. Conclusions are expected to not only address the immediate result of the analysis (e.g. that the component is strong enough or sufficiently designed), but also include recommendations for improvement. For example, a part that is intended to support a 20 psi internal pressure but that is analyzed and shown to be capable of withstanding 500 psi internal pressure is clearly over-built. A suggested improvement in such a case could be to make the component from a thinner material, saving significant cost; substituting a weaker but cheaper material is another such improvement.

All reports are submitted in a template format which is shared with the students at the beginning of the course in an editable file. The template includes a cover sheet with identifying details (project name, author, faculty advisor, etc.) and an abstract.

In the fall semester, 2023, six tutors received WATTS training—two humanities majors, a business major, a science major, and two engineering majors. The standard content and training method were used, which involves a description of the assignment given by the course instructor using illustrations from poorly- and well-written report samples, in collaboration with the tutor supervisor, who facilitates the discussion with the tutors. In addition, for this project, the instructor gave examples of critical thinking challenges that students face when designing solutions to problems posed by their corporate sponsors. It is routine procedure for all tutors of the learning center to complete a standard log that contains a box for free-form comments describing the session. During this training, the tutors were given directions to comment specifically on their ability to understand the project and whether the student answered their questions in a way that increased the tutor’s understanding. A separate sheet with those directions was provided in addition to the log.

Tutors posted their available hours on TutorTrac, a commercial scheduling software program. Times were available by appointment and drop-in. Students were encouraged to make appointments. Five of the six tutors met with students. Of those tutors, two were English majors, one was an Environmental Science major, one was a Finance major, and one was a Mechanical Engineering major.

A total of thirty senior design reports were tutored. Data from six of the MET reports were not included for the following reasons: one was a revision of a previously tutored paper, one failed to provide a first draft for assessment purposes, three were reports for different assignments (reports assigned in the same course but for a different purpose), and in the last case, the student came to the tutor's drop-in hours at a very busy time and the tutor was only able to devote a minimal amount of time to review the report. Of the twenty four reports, eleven were tutored by an English major, eight were tutored by a finance major, and five were tutored by an ME major.

The tutors' free-form comments were categorized using the Explanation of Issues category of the American Association of Colleges and Universities' (AAC&U) Critical Thinking VALUE Rubric. The instructor assessed the students' critical thinking using the VALUE rubric. Differences between tutor comments and report quality were compared to evaluate tutor feedback. Tutors completed an additional quantitative form that provided data regarding the level of student engagement during the session.

The reports were assessed using the "Explanation of Issues" dimension of this rubric. The scale of performance for this dimension is shown in table 1.

Table 1: Row 1 of the AAC&U Critical Thinking Rubric

Rating	(AAC&U) Critical Thinking VALUE Rubric: Explanation of Issues Criterion
4	Issue/problem to be considered critically is stated clearly and described comprehensively, delivering all relevant information necessary for full understanding.
3	Issue/problem to be considered critically is stated, described, and clarified so that understanding is not seriously impeded by omissions.
2	Issue/problem to be considered critically is stated but description leaves some terms undefined, ambiguities unexplored, boundaries undetermined, and/or backgrounds unknown.
1	Issue/problem to be considered critically is stated without clarification or description.

Results

Student report data

Some of the data points being compiled and examined include an average score based on ratings using the Critical Thinking VALUE Rubric.

The before and after assessments were plotted relative to each other ("before" as "x" and "after" as "y.") The results showed only a very weak correlation between the variables: $R^2 = 0.31$ in Table 2 below.

Table 2: Results of VALUE Rubric assessments of the MET reports

Before score	After =1	After =2	After=3	After =4	Total
Before = 1	7	5	1	0	13
Before = 2	1	4	3	0	8
Before = 3	0	1	2	0	3
Before = 4	0	0	0	0	0
Total	8	10	6	0	24

The pre-tutoring average score was 1.58 After tutoring, the average score rose to 1.92.

Of the twenty-four reports, two showed declines, fourteen remained steady, eight showed some improvement (+1), and one showed marked improvement (+2). These data are summarized in table 3.

Table 3: Results of VALUE Rubric assessments by level change

VALUE Rubric Ratings	Level 1	Level 2	Level 3	Level 4	Total
Level prior to tutoring	13	8	3		24
No change after tutoring	7	4	2		13
Increased one level	5	3			8
Increased two levels	1				1
Declined 1 level		1			1
Declined 2 levels			1		1

Three tutors contributed to the tutoring of the reports. Only one was a STEM major. The STEM major tutor tutored five students, for which the average critical thinking assessment rose from a 1.2 to a 2. For the nineteen reports tutored by non-STEM tutors, the average critical thinking assessment rose from a 1.68 to a 1.89.

Tutor survey data

Reports were also sorted by the extent to which the student could explain the project to the tutor. The log had a free form box for the tutors to respond to the following prompt: "Ask the student to describe the project. Comment on your ability to understand the project and whether or not the student was able to answer your questions in a way that increased your understanding." The results can be seen below in table 4.

Table 4: Tutor assessments of students' ability to explain their draft reports

VALUE Rubric Rating Levels	No. of Reports	Report Scores	Level 1	Level 2	Level 3	Level 4	Average
Student could fully explain the report	16	Pre-Tutoring	7	6	3		1.75
		Post-Tutoring	3	8	5		2.13
Student could only partially explain the report	7	Pre-Tutoring	6	1			1.14
		Post-Tutoring	5	2			1.28
Student could not explain the report	1	Pre-Tutoring		1			n/a
		Post-Tutoring			1		n/a
TOTAL Pre-Tutoring	24	Pre-Tutoring	13	8	3		
TOTAL Post-Tutoring	24	Post-Tutoring	8	10	6		

For the one report for which the tutor had assessed the student to have no ability to explain the project, the relatively high first draft VALUE assessment of "2" and the increase to "3" after tutoring suggest that factors other than critical thinking ability contributed to the student's perceived inability to explain the project. Due to the small size of this subset of the data, meaningful conclusions could not be drawn.

The level of collaboration between tutors and students has an impact on the type and quality of feedback that tutors are able to give STEM students, particularly when the tutors are not in STEM majors. Data from an earlier study has demonstrated that student/tutor collaboration increased significantly when tutors received WATTS training [8]. The data displayed in table 5 below were collected from tutors immediately after their appointments with students. These data are predominately positive, with the majority of responses in some level of agreement (75%). It should be noted that two tutors, both in non-STEM majors, visited the class prior to tutoring.

Previous research [9] has demonstrated that tutors and students define the term "content" very differently. STEM students define the content as the data presented, while writing tutors evaluate the report on rhetorical principles, such as organization and clarity. Only one student indicated that tutors would need specialized knowledge to understand the content of the report, which is particularly relevant when tutors pose questions to clarify areas of the report that they do not understand.

Table 5: Tutor assessments of students' collaboration during tutoring

	Strongly Agree	Agree	Somewhat Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	Total
Student took notes during the session	21	0	0	0	0	3	24
Student asked questions during the session	15	0	0	0	0	9	24
Student seemed receptive to my suggestions	6	16	1	0	1	0	24
Student wanted to understand the reasons/rules behind my suggestions	2	10	1	0	11	0	24
Subtotal	44	26	2	0	12	12	96
Student felt that specialized knowledge was needed to understand the paper's content	1	0	0	0	0	23	24

Conclusions

The data was inconclusive as to whether the WATTS-trained tutors could help improve student critical thinking skills. On the one hand, statistical analysis using the AAC&U VALUE critical thinking skills rubric showed only a weak correlation. However, 9 of the 24 reports showed improvement based on the rubric while only two showed a decline. Additionally, after meeting with the tutor, students tended to be better able to fully explain their report.

Given that there was no baseline comparison for this study, it is unclear if the use of a WATTS-trained tutor provided more benefit than one who was not WATTS-trained. However, this study shows that the WATTS method might be used as a springboard for many potential improvements in student writing and critical thinking skills.

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[2] Bodenhamer, J., & Weissbach, R., & Pflueger, R. C., & Renguette, C. C., & Sorge, B., & Dasgupta, A., & Edinbarough, I. (2023, June), *Board 121: Using Tutor-led Support to Enhance Engineering Student Writing for All* Paper presented at 2023 ASEE Annual Conference & Exposition, Baltimore, Maryland.

[3] Clippinger, D., Pflueger, R., Nozaki, S. (2022, June) *Using Writing Center Peer Tutors as a Means to Improve Mechanical Engineering Technology Student Writing* Paper presented at 2022 ASEE Annual Conference and Exposition, Minneapolis, Minnesota.

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