

# AI Mentors for Student Projects: Spotting Early Issues in Computer Science Proposals

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## Abstract

When executed well, project-based learning (PBL) engages students' intrinsic motivation, encourages students to learn far beyond a course's limited curriculum, and prepares students to think critically and maturely about the skills and tools at their disposal. However, educators experience mixed results when using PBL in their classrooms: some students thrive with minimal guidance and others flounder. Early evaluation of project proposals could help educators determine which students need more support, yet evaluating project proposals and student aptitude is time-consuming and difficult to scale. In this work, we design, implement, and conduct an initial user study ( $n = 36$ ) for a software system that collects project proposals and aptitude information to support educators in determining whether a student is ready to engage with PBL. We find that (1) users perceived the system as helpful for writing project proposals and identifying tools and technologies to learn more about, (2) educator ratings indicate that users with less technical experience in the project topic tend to write lower-quality project proposals, and (3) GPT-4o's ratings show agreement with educator ratings. While the prospect of using LLMs to rate the quality of students' project proposals is promising, its long-term effectiveness strongly hinges on future efforts at characterizing indicators that reliably predict students' success and motivation to learn.

**Keywords:** project-based learning, generative AI in education, learning analytics

## 1. Introduction

Project-based learning puts students in charge of their own education, giving them the freedom to decide what to learn, what to create, and what success means for them. It is an approach that intends to mimic real life, where answers are not easy to find, and success requires curiosity, critical thinking, and resilience. PBL is frequently used in computer science classes because it encourages students to test their understanding against real-world problems, develop essential project management skills, and explore industry tools and practices outside of the standard classroom curriculum.

However, PBL has shown mixed effectiveness in the classroom, with learning and motivation depending on students' prior ability, educators' ability to support specific projects and topics (Barnes and Bramley, 2008), and whether the project idea originated from students or teachers (Pucher and Lehner, 2011). Evaluating project proposals may help educators identify which students require additional guidance or alert educators to major issues that could consume limited motivation, time, and resources. Yet evaluating project proposals

is challenging and time-consuming, requiring educators to review freeform text on a broad range of topics and infer student aptitude from incomplete or vague details.

In this work, we design, implement, and conduct a user study for a software system that collects project proposals and aptitude information that may help educators determine whether a student is ready to engage with PBL. Our design elicits proposals for a high school-level computer science project where students build and design an interactive web application or video game. Our project proposal form asks users to (1) describe a problem they want to work on, (2) propose a solution, (3) recall and analyze design inspirations, (4) predict the effects of their design, (5) plan to evaluate and iterate on their project, (6) describe skills they want to develop, and (7) connect those skills to computer science careers, technical tasks, and popular industry technologies.

Our preliminary user study ( $n = 36$ ) showed our system could engage users' intrinsic motivation, with 88.8% of users wanting to use our system in the future to choose skills and technologies to learn more about, and 91.6% of users wanting to use our system in the future to design project ideas that motivate them to learn more. Two educators and GPT-4o independently graded the quality of each project proposal according to a 29-item rubric. Educators and GPT-4o showed promising agreement on the relative quality of proposals and tended to give lower quality scores to users with less computer science experience.

Our findings suggest that LLMs show promise for scaling the automatic grading of project proposals; however, the effectiveness of using LLM grades to guide instructional design decisions hinges on whether project proposals and grading criteria contain information that reliably predicts whether a student can benefit from project-based learning.

## 2. Related Work

[Barnes and Bramley \(2008\)](#) found that student engagement in an Algebra 1 class improved when activities incorporated opportunities for choice, goal-setting, and one-on-one interactions with teachers. Similarly, [Pucher and Lehner \(2011\)](#) reported increased motivation among students when employing PBL in computer science classes. However, both studies highlighted challenges tied to students' limited meta-cognitive skills and domain knowledge. For instance, many students struggled to maintain their goal portfolios ([Barnes and Bramley, 2008](#)), and student-defined projects received significantly lower grades from faculty ([Pucher and Lehner, 2011](#)). [Kirschner et al. \(2006\)](#) critique PBL's effectiveness in supporting student learning, arguing that under minimal guidance, inexperienced students often struggle to develop effective strategies for independently searching for and applying information. Recent advances in LLMs enabled new types of learning technologies in various educational domains ([Kasneci et al., 2023](#)). LLMs' ability to provide feedback to student submissions ([Botelho et al., 2023](#)) and to support student self-reflection ([Yazici et al., 2024](#)) inspires the present development of a system to support effective execution of PBL.

## 3. System Design

Our software system is implemented as an React.js and firebase-based web application that collects project proposals and aptitude information that may help educators determine whether a student is ready to engage with PBL. The system logs the time and type of

user actions, such as keystroke patterns, answers to multiple-choice selections, and when users navigate away from and back to the web page. Our system first asks users questions about their aptitude for problem-solving, experience with computer science technologies, and prior experience with PBL. Then the system asks users to write down their idea for a high school-level computer science project on developing an interactive web application or video game. Our project proposal form, adapted from [CS Pathway \(2024\)](#); [Byrdseed \(2009\)](#), asks users to (1) describe a problem they want to work on, (2) describe the software they want to build, (3) recall and analyze design inspirations, (4) predict the effects of their design, (5) make a plan to evaluate and iterate on their project, (6) self-evaluate using a 10-point quality checklist, (7) describe skills they want to develop, and (8) connect those skills to computer science careers, technical tasks, and popular industry technologies. Due to space limitations, we included UI images in Appendix A.

#### 4. System Evaluation

Each project proposal was independently evaluated by two human domain experts with experience as head teaching assistant (TA) for undergraduate computer science classes and GPT-4o ([Hurst et al., 2024](#)). All raters used the same 23-item quality checklist with four subtasks: (1) 10-question quality checklist students had used to self-assess their own work, (2) 3 questions judging the quality of 3 skill descriptions written by students, (3) 9 questions judging the appropriateness of skill-career pairings ( $3 \times 3$ ), and (4) an overall quality judgment question (“I would recommend a student include this project on their resume.”). We did not perform any prompt-engineering on GPT-4o beyond evaluating subtasks and each of the student’s three written skill descriptions in a separate prompt to avoid holistic evaluations. We provide the evaluation rubric in Appendix B and GPT-4o prompts in Appendix C.

This evaluation protocol captures two main signals of user readiness for PBL. First, by comparing users’ self-assessments to expert human evaluations on the same 10-point **quality checklist** adapted from [WPI CS 4518 \(2024\)](#) and [Lawlor \(2012\)](#), we could determine whether users can accurately report on the quality of their own work.

Second, by asking human expert raters to classify the **quality of skill descriptions** (“Good” vs. “Irrelevant”, “Vague”, or “Not Core Computer Science Skill”) of three skills users want to develop by working on their project and the **appropriateness of how users matched those skills to predefined mentor profiles** (such as “Data Scientist” or “Software Developer”), career-specific tasks, and trending technologies sourced from the O\*Net Online Database ([National Center for O\\*NET Development, 2024](#)), we could capture signal on whether users’ are capable of identifying perspectives and types of industry knowledge relevant to their project ideas. Users were explicitly instructed to leverage internet resources for assistance if needed, so this metric was intended to measure general reasoning and searching ability rather than ability to recall specific definitions. However, misinterpreting instructions, inability to parse technical language used by O\*Net Online Database ([National Center for O\\*NET Development, 2024](#)), and shoehorning skills to match one of a limited number of options could weaken the strength of this measurement. We sanity check the quality of our grading criteria by comparing scores from users with higher levels

of computer science experience against users with less experience. We expect that students with computer science experience should be able to write higher quality project proposals.

Additionally, we asked the human experts raters and GPT-4o to answer a question meant to capture the overall quality of the project proposal (“I would recommend a student include this project on their resume. Yes/No”).

We checked the motivational benefits of our project proposal writing activity with a post-activity experience survey.

**Experimental Procedure.** We recruited 40 participants online via Prolific. Our recruitment call was shown to crowd workers (i) 18 years or older; (ii) located in the USA; (iii) fluent in English; (iv) possess at least a high-school (HS) degree or equivalent; (v) using a desktop device (no mobile or tablets); and (vi) answered yes to “Are you a student?” on Prolific (see recruitment call in Appendix D). 2 participants were filtered out for not completing the activity, and 2 were filtered for failing attention checks. Of the 36 remaining participants, 17 were 18-25 years old, 14 were 26-35 years old, and 5 were over 46 years old. 25 were male, 11 were female. 11 participants reported Computer Science as their field of work/study, and 19 claimed to have computer science experience, i.e., have built a website or interactive application before using “Programming Language (e.g., Python, JavaScript)”, “Backend Technologies (e.g., Node.js, Django, Flask)”, “Cloud Platforms (e.g., Firebase, AWS)”, and/or “Testing and Deployment (e.g., unit testing libraries, Docker)”. Interestingly, some of these users claimed experience in categories like Backend Technologies or Cloud Platforms while simultaneously reporting no experience with Programming Languages. This discrepancy suggests a potential need for more fine-grained and specific questions to accurately capture their technical experience.

All participants encountered the same set of activities and questions in the same order, and could not go back to previous stages. Participants were told the activity would take 30-45 minutes, but we did not control for time in any phase. The median time to complete the activity was 40 minutes. The recruitment and study process was approved by CMU’s Institutional Review Board (research study 2024-00000405).

#### 4.1. Results

As shown in Table 1, human expert raters and GPT-4o showed promising agreement on the relative quality of proposals. As shown in Table 2, human expert raters and GPT-4o tended to give lower quality scores to users with less computer science experience.

**Skill Classification.** Human raters and GPT-4o classified 50% of skills as irrelevant, vague, or not relevant to computer science ( $> 80\%$ ,  $\kappa > 0.6$ ). Consistent across all three graders, students with less computer science knowledge had an average of 1 out of 3 skills accepted, while students with more computer science knowledge had an average of 2 of 3 skills accepted.

**Appropriateness of Skill Pairing Classification.** The low quality of skills written down by the students might have made the subsequent activity to pair skills with careers, tasks, and technologies more challenging to grade. Human rater agreement was minimal (68%,  $\kappa = 0.25$ ). GPT-4o showed weak agreement with TA 1 (74%,  $\kappa = 0.46$ ) and minimal agreement with TA 2 (67%,  $\kappa = 0.20$ ).

Table 1: Rater Agreement. We report agreement percentage and Cohen’s  $\kappa$  value between the two human expert raters (TA1 and TA2) and GPT-4o with respect to the 4 grading subtasks. As an overall index of agreement, we compute kappa for all rater pairs then report the arithmetic mean of these estimates.

	TA1 / TA2	TA1 / GPT-4o	TA2 / GPT-4o	Avg. $\kappa$
Skill Quality Classification	86.1%, $\kappa = 0.72$	84.3%, $\kappa = 0.68$	81.5%, $\kappa = 0.63$	0.68
Skill Pairing Classification	68.6%, $\kappa = 0.26$	74.2%, $\kappa = 0.46$	67.2%, $\kappa = 0.20$	0.29
Quality Checklist	87.2%, $\kappa = 0.49$	71.4%, $\kappa = 0.28$	74.7%, $\kappa = 0.28$	0.38
Recommend for Resume	80.6%, $\kappa = 0.50$	75.0%, $\kappa = 0.43$	77.8%, $\kappa = 0.45$	0.46

Table 2: Mean Positive Grades for Experienced vs. Novice Students. Each cell represents the mean proportion of student responses graded positively per subtask and rater, grouped by whether students reported having previous computer science experience. Subtasks averaged over 3, 6, 10, and 1 rater items respectively

Task	Experience	TA1	TA2	GPT-4o	Self-Rating
Skill Classification	Novice	35.3%	39.2%	31.4%	-
	Experienced	70.2%	68.4%	68.4%	-
Skill Pairing Classification	Novice	60.8%	86.9%	57.5%	-
	Experienced	53.7%	92.4%	64.9%	-
Quality Checklist	Novice	83.5%	82.4%	58.2%	85.9%
	Experienced	84.7%	90.0%	71.1%	95.8%
Recommend for Resume	Novice	58.8%	70.6%	58.8%	-
	Experienced	78.9%	84.2%	73.7%	-

**Quality Checklist.** GPT-4o’s scores tended to be lower than either human rater’s scores, leading to lower agreement between GPT-4o and humans (71 – 75%,  $\kappa = 0.28$ ). However, as seen in Figure 1, GPT-4o roughly maintained the rank of student project proposal quality relative to each other, shown by GPT-4o’s Spearman correlations with TA 1’s (Spearman=0.70) and TA 2’s (Spearman=0.53). In contrast, students’ self-evaluations had a much weaker correlation with either human expert’s ratings (Spearman=0.16, Spearman=0.38).

**Experience Survey.** As shown in Figure 2, the large majority of users enjoyed the process of writing project proposals, with 88.8% of users wanting to use our system in the future to choose skills and technologies to learn more about, and 91.6% of users wanting to use our system in the future to design project ideas that motivate them to learn more.

## 5. Discussion and Limitations

Our findings suggest that LLMs show promise in scaling the automatic grading of project proposals; however, the effectiveness of using LLM grades to guide instructional design decisions hinges on whether project proposals and grading criteria contain information that

	TA 1	TA 2	GPT-4o	Self
TA 1	1.00	0.74	0.70	0.16
TA 2	0.74	1.00	0.53	0.38
GPT-4o	0.70	0.53	1.00	0.23
Self	0.16	0.38	0.23	1.00

Figure 1: Spearman correlation of students’ total score on the 10-point quality checklist. Although GPT-4o’s scores for the quality checklist task are lower than both teaching assistants and student self-evaluations, GPT-4o’s scores preserve the rank order of teaching assistants’ scores better than students’ self-evaluation scores do.

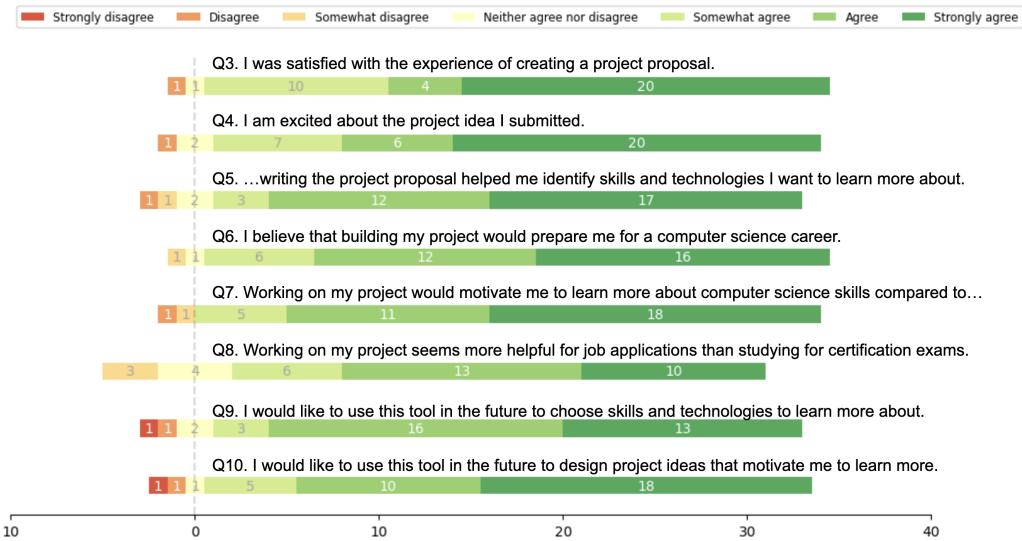


Figure 2: **Experience Survey, Response Counts.** The majority of users reported high level of excitement, motivation, and wanting to use the activity in the future to choose skills and technologies to learn more about.

reliably predicts whether a student can benefit from project-based learning. There are several limitations of our work that we now discuss.

First, in an optional feedback text field, human expert raters noted that several project proposals contained vague implementation details and skills, making it challenging for raters to determine whether crowd workers had appropriately paired their skills to computer sci-

ence careers, tasks, or technologies (inter-TA agreement of 68.61%,  $\kappa = 0.26$ ). To address these concerns, we gave raters a skill classification rubric to quantify the vagueness and irrelevance of skills, achieving moderate agreement among human expert raters (inter-TA agreement of 86.11%,  $\kappa = 0.72$ ). Consistent across both human expert ratings and GPT-4o ratings, students with less computer science knowledge wrote an average of 1 out of 3 acceptable skills, while students with more computer science knowledge wrote an average of 2 of 3 acceptable skills. The effectiveness of project-based learning relies on students' recognizing the necessary skills to develop and maintaining motivation to learn them. While our current work focuses on leveraging LLMs to evaluate issues in project proposals, future iterations of our system may be able to improve students' success in project-based learning by helping beginners gain an awareness of specific and contextually relevant computer science skills.

Second, our study examines project proposals written by crowd workers who were 18 years or older and identified as students (answered yes to "Are you a student?"). In this preliminary work, our aim was to gather project proposals from students with diverse backgrounds and varying degrees of familiarity with computer science. This approach attempted to capture the potential diversity of students that might enroll in introductory computer science courses at the high school or undergraduate level. The trends observed in the collected proposals can inform the design of future tools to support students in writing project proposals. Future work will investigate whether trends and issues observed in crowd workers' project proposals transfer to classroom assignments.

Third, while generative AI-based learning technologies like our GPT-4o-based system show promise, they also incur regular costs due to API calls, raising important questions about equity and accessibility in educational contexts. While we use GPT-4o, we should be able to use our LLM-powered grading methodology with any generative large language model. Future work could explore the application of different LLMs for this task, including open-source models.

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## Appendix A. Illustrations of User Interface

Here, we provide additional details regarding the system workflow and user interface. The system guides users through a series of steps prompting the user to (1) describe a problem they want to work on (Figure 3 and 4), (2) propose a solution (Figure 5), (3) recall and analyze design inspirations (Figure 4), (4) predict the effects of their design (Figure 6), (5) plan to evaluate and iterate on their project, (6) describe skills they want to develop, and (7) connect those skills to computer science careers, technical tasks, and popular industry technologies (Figure 7, 8, 9, 10 and 11).

## Project Assignment

### Introduction

On one hand, computer science is such an exciting discipline because of its rapid pace of innovation. On the other hand, mastery of computer science is challenging because it evolves so rapidly that any frozen skill set (however masterful) risks becoming outdated. In such a dynamic environment, what skills will stand the test of time and continue to serve you, long after many of the precise methods taught in school go out of fashion?

Perhaps the most important meta-skill to acquire is to be able to think like a problem-solver. Thinking like a problem-solver means (i) accessing new knowledge from messy scientific literature and the internet, pulling out the useful and correct bits from articles and papers while discarding (or correcting) mistakes; (ii) applying new methods and ideas to real problems that you are trying to solve.

### Possible Topics

Propose a project idea centered in one or more of these project topics.

- **Interactive Web Development:** Design and program an web app or website for a specific purpose. Practice using web frameworks, querying a database, and adding interactivity. Get started by following the '<https://tutorial.djangogirls.org/en/>' tutorial to make a blog using Python, Django web framework, and a SQLite database.
- **Video Game Development:** Create a 2D or 3D game using Unity and C#. Practice using the power of object oriented programming (OOP) languages to organize and extend your game idea. Get started by following tutorials from '<https://learn.unity.com/>'.
- **Write Useful Programs and Scripts:** Want to make computers do the hard work for you? Think of a project idea that involves automating everyday tasks, analyzing large amounts of data, or getting stuff done fast.
- **Practice Using Cloud Computing:** Use the Cloud to store large amounts of data and quickly deploy your programs to millions. Platforms like Google Cloud, Amazon Web Services, or Microsoft Azure support cloud hosting and deployment, cloud data storage, or real-time collaboration.

See Example

Figure 3: Introduction of project-based learning (PBL) task and possible projects.

**STEP 1 of 3.**

**What Do You Want To Work On?**

**Q1.** Choose at least one COMPUTER SCIENCE topic you are interested in learning more about.

- Interactive Web Development
- Video Game Development
- Write Useful Programs and Scripts
- Practice Using Cloud Computing

Choose at least 1

**Q2 - Background/Problem.** Come up with a project idea using the topic you selected above. Briefly describe the focus of your project and motivate its importance.

*Your Response*

Write at least 5 more words

**Q3 - Objectives.** Describe the software you want to build and how it will work

*Your Response*

Write at least 5 more words

Figure 4: In the first step, the system prompts the student to specify a project and describe background and objectives.

**STEP 2 of 3.**

Find Inspirations



"If I have seen further, it is by standing on the shoulders of Giants" - Isaac Newton

**Q4 - Find Inspiring Examples.** Name two existing SOFTWARE PROGRAMS that have implemented features similar to the ones you want to create in your project. If you can't think of examples, you can use the Internet. Try to write down examples that delight you.

- 1.
- 2.

Write down two items

**Q5.** Which existing features are easiest to copy? Which ones are a good fit for your project?

Your Response

Write at least 5 more words

**Q6.** Which existing feature would you learn the most from building? Is it a good fit for your project?

Your Response

Write at least 5 more words

Figure 5: In the second step, the system prompts the student to find inspiration and to connect the problem to existing examples.

**STEP 3 of 3.**  
Find Motivation to Keep Learning

**Q7 - Your Design.** Name an interesting difference between your project idea and existing solutions. What effect could this difference have?

My Design:

Predicted Effect:

Write at least 5 more words

**Q8 - Quick Feedback Loop.** Select the types of feedback you plan on collecting to evaluate your project (and motivate yourself to build better iterations of your project):

Choose at least 1

**Acceptance Testing.**

- Watch people use the software
- Interview users
- Analyze user experience surveys

**Performance Testing.**

- Measure time to perform actions
- Measure success at completing an action
- Write unit tests or test code for bugs

**Comparison Points.**

- Compare your features against existing solutions
- Compare two versions of your design
- Check quality using common sense metrics or against industry standards

Figure 6: In the third step, the system prompts the student to specify their design in greater detail.

## Quality Checklist

WOULD SOMEONE ELSE UNDERSTAND WHAT YOU ARE TRYING TO DO?

**Background/Problem.**

*Your Response*

This proposal describes a specific focus and motivation

No  Yes

This proposal describes a good use of computer science skills

No  Yes

Figure 7: The system prompts the student to reflect on their proposal in terms of background and problem.

**Objectives.**

*Your Response*

This proposal describes specific, tangible features that will be built in the project

No  Yes

Working on the project is relevant to learning about

No  Yes

Figure 8: The system prompts the student to reflect on their proposal in terms of project objectives. After answering Q1 (choosing topic), the second question in the checklist is populated with the chosen topic's name.

**Related Work.**

*Your Response*

**Could Learn From...**

*Your Response*

The proposal analyzes similar products, papers, or applications

No  Yes

Figure 9: The system prompts the student to reflect on their proposal in terms of related work and references.

**Testable Design Hypothesis.**

My Design:

Predicted Effect:

Complete!

The design hypothesis describes a specific feature that will be built in the project

No  Yes

The predicted effects of the design hypothesis can be tested quickly

No  Yes

Figure 10: The system prompts the student to reflect on their proposal in terms of design hypothesis.

**Evaluation Plan.**

*Your Response*

The project has an objective measure of success or learning

No  Yes

The design hypothesis has an objective measure of success or learning

No  Yes

The evaluation plan can be carried out within a 4 week sprint

No  Yes

Figure 11: The system prompts the student to reflect on their proposal in terms of evaluation plan.

### Connect Your Idea to COMPUTER SCIENCE Skills



CS Skills + Your Creative Idea = Best Friends <3

Make sure your project allows you to practice some useful, in-demand skills. Clearly articulating what skills you want to work on in this project will help you and the (hypothetical) teaching staff find resources personalized to your needs, help you distinguish yourself at interviews and recruiter talks, and be more prepared for the next challenge that comes your way.

**Q1. Skills** - Write down three skills you want to develop by working on your computer science project. Think about skills that might be handy for projects you want to try in the future.

- 1.
- 2.
- 3.

Please write down three items.

Figure 12: The system prompts the student to describe three skills they want to develop while working on their project.

**SKILL1.**

### Connect "Visualizing Data" to CS Careers

**Q2a - Perspective.** When learning "Visualizing Data", I would like to hear advice from...

- Web Developers
- Video Game Designers
- Software Developers
- Computer Programmers
- Data Scientists
- Business Intelligence Analysts
- Statisticians
- Computer Systems Engineers/Architects
- Database Architects

Figure 13: The system prompts the student to connect the first skill to a mentor whose perspective would be valuable.

**Q2b - Practice.** Which Data Scientists' task is most similar to "Visualizing Data"?

- Analyze, manipulate, or process large sets of data using statistical software.
- Apply feature selection algorithms to models predicting outcomes of interest, such as sales, attrition, and healthcare use.
- Apply sampling techniques to determine groups to be surveyed or use complete enumeration methods.
- Clean and manipulate raw data using statistical software.
- Compare models using statistical performance metrics, such as loss functions or proportion of explained variance.
- None of the Above

Figure 14: The system prompts the student to connect the first skill to one of the top 5 important tasks for their selected mentor's career (tasks sourced from O\*Net Online).

**Q2c - Tools.** Which Data Scientists' tools do you want to learn to be better at "Visualizing Data"?

Focus on tools to analyze, manipulate, or process large sets of data using statistical software

Choose at least 1

**Object or component oriented development software.**

- Python
- R
- Oracle Java
- Scala
- C++

**Data base user interface and query software.**

- Structured query language SQL
- Amazon Web Services AWS software
- PyTorch
- pandas
- NumPy

**Business intelligence and data analysis software.**

- Tableau
- Apache Spark
- Microsoft Power BI

Figure 15: The system prompts the student to connect the first skill to tools and technologies associated with their selected mentor's career (technologies sourced from O\*Net Online).

## Appendix B. Human Expert Evaluation Rubric

Here, we provide a crowd worker’s project proposal and the 23-item quality checklist that human experts and GPT-4o used to grade the project proposals. The rubric had four subtasks:

- Using the same quality checklist students used to self-assess their own work (10 items).
- Judging the appropriateness of skill-career pairings (9 items; 3 items per skill).
- An overall quality judgment question (“I would recommend a student include this project on their resume”) (1 item).
- Judging the quality of skill descriptions written by students (3 items; 1 item per skill). This set of questions was asked in a separate form developed to capture factors that could explain low rater agreement on the appropriateness of skill-career pairings.

## Grade Project Proposals

Grade 36 project proposals collected by our survey

For each project, answer 20 multiple choice questions (+ optional open response if you have more feedback)

Figure 16: Evaluation task description, shown to the human experts.

Context for Grading "Skills" + "Career" + "Technologies"  
We may want to use students' skill + career + tool choices to aid the design of  
personalized learning tools in the future.

The question is whether students (without explicit CS background) can easily navigate a full and static list of CS career tools/technologies and choose relevant and appropriate ones to learn, or whether there seems to be a pressing need to use AI or rules to reduce the size of the menu.

Students answered this progression of questions:

**Q1 - Skills.** Write down three skills you want to develop by working on your computer science project. Think about skills that might be handy for projects you want to try in the future.

**Q2a - Perspective.** When learning "SKILL 1", I would like to hear advice from...

- Web Developers
- Video Game Designers
- Software Developers
- Computer Programmers
- Data Scientists
- Business Intelligence Analysts
- Statisticians
- Computer System Engineers/Architects
- Database Architects

**Q2b - Practice.** Which CAREER 1's task is most similar to "SKILL 1"?

- 5 most important career-relevant tasks from O\*Net Online Database

**Q2c - Tools.** Which CAREER 1's tools do you want to learn to be better at "SKILL 1"?

- All "HOT TECHNOLOGIES" for that career from O\*Net Online Database

Then they saw a summary of their choices in the following format

...

Use C + C++ for "**Advanced Rendering**"

Similar to **Video Game Designers** working to *Devise missions, challenges, or puzzles to be encountered in game play.*

...

- \* Bold + Quotes: "**skill**"
- \* Bold: **career**
- \* Italics: **task**

**Next**

**Clear form**

Figure 17: Instructions for evaluating project proposals, shown to the human experts.

UUID: 0205bb5a (#1/36)

**Project Title:** "Rendering Techniques for Video Game Optimization"

**Hypothetical "Describe this Project to an Interviewer":** "I started this project because of my love for video games and my interest in improving rendering performance. My goal was to create a system that adjusts rendering quality based on hardware capabilities. The biggest challenge was optimizing performance across different devices, which I tackled by implementing adaptive rendering techniques. My proudest achievement was boosting rendering speeds by 20% and improving frame rates by 15%, making the game more accessible and visually appealing for a wider audience."

**Background/Problem.**

**Briefly describe the focus of your project and motivate its importance:**

"While videogame rendering has improved over the years, it could still potentially be quicker. How might we achieve this?"

(UUID: 0205bb5a, Q1) **This proposal describes a specific focus and motivation** (beyond describing video game design, interactive web design, writing useful programs and scripts, or practicing cloud computing in general) \*

Yes

No

(UUID: 0205bb5a, Q2) **This proposal describes a good use of computer science skills** \*

Yes

No

Figure 18: Items for evaluating a student's project proposal in terms of background and problem.

Objectives.

**Topic:** Video Game Development

**Describe the software you want to build and how it will work:**

"I want to build software that will push render speeds to their limits."

(UUID: 0205bb5a, Q3) **This proposal describes specific, tangible features that will be built in the project** \*

Yes

No

(UUID: 0205bb5a, Q4) **Working on the project is relevant to learning about TOPIC** \*

Yes

No

Figure 19: Items for evaluating a student's project proposal in terms of objectives.

**Related Work.**

**Inspirations:**

1. Unreal engine
2. Unity

**Which existing features as easiest to copy:**

"High-quality textures and post-processing effects."

**Which existing features would you learn the most from building:**

"I would likely learn the most from building Fluid animation. It is a good fit because using this feature I could build realistic tests for render speeds."

(UUID: 0205bb5a, Q5) **The proposal analyzes similar products, \* papers, or applications**

- Yes  
 No

Figure 20: Items for evaluating a student's project proposal in terms of related work.

**Testable Design Hypothesis.**

**Name an interesting difference between your project idea and existing solutions. What effect could this difference have:**

"My Design: My project will implement adaptive rendering techniques that dynamically adjust the level of detail

**Predicted Effect:** This will make it so that games run smoothly no matter the power of the machine, including fast render speeds."

(UUID: 0205bb5a, Q6) **The design hypothesis describes a specific feature that will be built in the project** \*

- Yes
- No

(UUID: 0205bb5a, Q7) **The predicted effects of the design hypothesis can be tested quickly** \*

- Yes
- No

Figure 21: Items for evaluating a student's project proposal in terms of design hypothesis.

**Evaluation Plan.**

**Select the types of feedback you plan on collecting to evaluate your project (and motivate yourself to build better iterations of your project):**

"Analyze user experience surveys + Interview users + Measure success at completing an action + Measure time to perform actions"

**Briefly describe how you will use each one to evaluate and improve small, manageable parts of your project:**

"I would like to release a test version of the app and interview users to gather perceived performance data. As well as measure the time it takes complete desired actions."

(UUID: 0205bb5a, Q8) **The project has an objective measure of \* success or learning**

- Yes
- No

(UUID: 0205bb5a, Q9) **The design hypothesis has an objective \* measure of success or learning**

- Yes
- No

(UUID: 0205bb5a, Q10) **The evaluation plan can be carried out \* within a 4 week sprint**

- Yes
- No

Figure 22: Items for evaluating a student's project proposal in terms of evaluation plan.

<p><b>Skill 1.</b> Use C + C++ for "<b>Advanced Rendering</b>" Similar to <b>Video Game Designers</b> working to <i>Devise missions, challenges, or puzzles to be encountered in game play.</i></p>
<p>(UUID: 0205bb5a, Q11) <b>The technologies chosen for learning skill 1 are a good fit</b> *</p> <p><input type="radio"/> Yes <input type="radio"/> No</p>
<p>(UUID: 0205bb5a, Q12) <b>The selected career is relevant to skill 1</b> *</p> <p><input type="radio"/> Yes <input type="radio"/> No</p>
<p>(UUID: 0205bb5a, Q13) <b>The selected task is relevant for learning skill 1</b> *</p> <p><input type="radio"/> Yes <input type="radio"/> No</p>

Figure 23: Items for evaluating whether student has matched their skill #1 to appropriate technologies, computer science career, and career task.

**Skill 2.**

Use Atlassian JIRA + C + C++ for "**Optimization**"

Similar to **Software Developers** working to Confer with data processing or project managers to obtain information on limitations or capabilities for data processing projects.

(UUID: 0205bb5a, Q14) **The technologies are a good fit for practicing skill 2** \*

Yes

No

(UUID: 0205bb5a, Q15) **The selected career is relevant to skill 2** \*

Yes

No

(UUID: 0205bb5a, Q16) **The selected task is relevant for learning skill 2** \*

Yes

No

Figure 24: Items for evaluating whether student has matched their skill #2 to appropriate technologies, computer science career, and career task.

**Skill 3 .**

Use C++ for "Cloud integration"

Similar to **Computer Systems Engineers/Architects** working to *Direct the analysis, development, and operation of complete computer systems.*

(UUID: 0205bb5a, Q17) **The technologies are a good fit for practicing skill 3**

- Yes
- No

(UUID: 0205bb5a, Q18) **The selected career is relevant to skill 3**

- Yes
- No

(UUID: 0205bb5a, Q19) **The selected task is relevant for learning skill 3**

- Yes
- No

Figure 25: Items for evaluating whether student has matched their skill #3 to appropriate technologies, computer science career, and career task.

**Project Plan**

**Steps**

1, Gain a deep understanding of advanced rendering techniques and optimization strategies.  
2, Begin developing the core rendering features and integrate basic optimization techniques.  
3, Refine and optimize the rendering features to improve performance.  
4, Finalize the project and document the process and findings.

**Resume Keywords:** "Real-time rendering, adaptive rendering, performance optimization, video game development, cloud computing integration."

(UUID: 0205bb5a, Q20) I would recommend a student include **this project on their resume.** \*

Yes  
 No

**(Optional)** Is there anything else you want to tell us about grading "**Rendering Techniques for Video Game Optimization**" project proposal? (UUID: 0205bb5a)

Your answer

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Figure 26: Item for evaluating overall quality and open-ended comments on the project proposal.

## Rate Skills

Rate each skill as either:

- **Irrelevant** - not obvious how this skill is relevant to the project description
- **Auxiliary** - the skill not a computer science technical career skill -- for example "Art design for video games", "researching on health and well-being", or non-technical project management skills like "communication" or "make documents"
- **Vague** - an overly broad computer science skill; giving concrete advice for improving this skill over the course of a project is difficult -- for example "coding" or "debugging"
- **Good** - practicing this skill will improve STEM or Computer Science knowledge – for example "front end development"

Figure 27: Instructions for classifying the skills written by students.

**0205bb5a (#1/36)**

**Background/Problem:** "While videogame rendering has improved over the years, it could still potentially be quicker. How might we achieve this?"

**Objectives:** "I want to build software that will push render speeds to their limits."

**Testable Design Hypothesis:** "My Design: My project will implement adaptive rendering techniques that dynamically adjust the level of detail"

**Predicted Effect:** This will make it so that games run smoothly no matter the power of the machine, including fast render speeds."

**Skills:**

1. Advanced Rendering
2. Optimization
3. Cloud integration

**0205bb5a: Skill 1 \***

- Irrelevant
- Auxiliary
- Vague
- Good

Figure 28: Project proposal and skill #1 classification question.

**0205bb5a: Skill 2 \***

- Irrelevant
- Auxiliary
- Vague
- Good

**0205bb5a: Skill 3 \***

- Irrelevant
- Auxiliary
- Vague
- Good

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Figure 29: The skill #1 and skill #2 classification questions.

### Appendix C. LLM-as-a-Judge Prompt GPT-4o

To produce ratings from GPT-4o, we call OpenAI API with the following prompt templates, populated with each project proposal's text. The rubric items are the same as the items used in the human expert grader's rubric given in Appendix B.

System Prompt - Quality Checklist & Resume Project

You are a teaching assistant. Your job is to check project proposals for quality and higher order thinking skills in Bloom's taxonomy (evaluation, synthesis). For each item in the checklist (Q1-Q11), respond with Yes or No.

User Prompt - Quality Checklist & Resume Project

Project Title: `` `project\_title` ``

Background/Problem.

Briefly describe the focus of your project and motivate its importance:  
`` `q2\_problem` ``

\* Q1. This proposal describes a specific focus and motivation (beyond describing video game design, interactive web design, writing useful programs and scripts, or practicing cloud computing in general)

\* Q2. This proposal describes a good use of computer science skills

Objectives:

Topic: `` `q1\_topic` ``

Describe the software you want to build and how it will work: `` `q3\_objective` ``

\* Q3. This proposal describes specific, tangible features that will be built in the project

\* Q4. Working on the project is relevant to learning about q1\_topic

Related Work.

Inspirations: `` `q4\_inspirations` ``

Which existing features are easiest to copy: `` `q5\_analysis\_copy` ``

Which existing features would you learn the most from building:  
`` `q6\_analysis\_learn` ``

\* Q5. The proposal analyzes similar products, papers, or applications

Testable Design Hypothesis.

Name an interesting difference between your project idea and existing solutions. What effect could this difference have: `` `q7\_your\_design` ``

\* Q6. The design hypothesis describes a specific feature that will be built in the project

\* Q7. The predicted effects of the design hypothesis can be tested quickly

Evaluation Plan.

Select the types of feedback you plan on collecting to evaluate your project (and motivate yourself to build better iterations of your project): `` `q8\_feedback` ``

Briefly describe how you will use each one to evaluate and improve small, manageable parts of your project: `` `q9\_evaluation\_plan` ``

\* Q8. The project has an objective measure of success or learning

\* Q9. The design hypothesis has an objective measure of success or learning

\* Q10. The evaluation plan can be carried out within a 4 week sprint

Project Plan.

Steps: `` `steps` ``

\* Q11. I would recommend a student include this project on their resume.

Desired format:

\* QX. {Yes | No}

System Prompt - Skill Pairing Classification

You are a teaching assistant. Your job is to check whether the skill students want to learn is appropriate for the listed career and career-specific task. The skill students want to learn is in double quotes. The mentor and the task are listed on the following line. For each item in the checklist (Q1-Q3), respond with Yes or No.

User Prompt - Skill Pairing Classification

Background/Problem: ` ``q2\_problem``

Objectives: ` ``q3\_objective``

Testable Design Hypothesis: ` ``q7\_your\_design``

Skill: ` ``skill``

\* Q1. The technologies chosen for learning the skill are a good fit.

\* Q2. The selected career is relevant to the skill.

\* Q3. The selected career-specific task is relevant for learning the skill.

Desired format: \* QX. {Yes | No}

System Prompt - Skill Classification

You are a teaching assistant. Rate each skill as either:

\* Irrelevant - not obvious how this skill is relevant to the project description

\* Auxiliary - the skill not a computer science technical career skill – for example “Art design for video games”, “researching on health and well-being”, or non-technical project management skills like “communication” or “make documents”

\* Vague - an overly broad computer science skill; giving concrete advice for improving this skill over the course of a project is difficult – for example “coding” or “debugging”

\* Good - practicing this skill will improve STEM or Computer Science knowledge – for example “front end development”

Respond with Irrelevant, Auxiliary, Vague, or Good.

User Prompt - Skill Classification

Background/Problem: ` ``q2\_problem``

Objectives: ` ``q3\_objective``

Testable Design Hypothesis: ` ``q7\_your\_design``

Skill: ` ``skill``

Desired format:

{Irrelevant | Auxiliary | Vague | Good}

## Appendix D. Recruitment Call Posted on Prolific



## Evaluating Support for Writing Project Proposals

By cs.cmu.edu

\$6.00 • \$12.00/hr | 30 mins | 40 places | Writing

**Purpose of this Study**

The purpose of the study is to explore what types of support help people write high-quality project proposals that demonstrate higher-order thinking. We will evaluate the effectiveness of aids such as assignment descriptions, brainstorming guides, skill databases, and AI-generated examples. Understanding pain points in the project proposal writing process will inform the design of future tools to support project-based learning using AI.

**Procedures**

The study will begin with a brief pre-task survey, consisting of questions on your familiarity with writing skills and awareness of computer science career concepts. Following this, you will be presented with a task to write a project proposal in an open-response format. Depending on the group you are randomly assigned to, you may receive limited support. After finishing the project proposal writing task, you will move onto a final part that consists of a few questions on your experience completing the task, demographic information, and ability to use your new knowledge to respond in related scenarios.

**Estimated Time Required for Participation**

The total estimated time for participation is 30-45 minutes.

**Participant Requirements**

This is a voluntary study, conducted for research purposes. To participate in this study, you must fit the following criteria.

- 1 . Be 18 or older
- 2 . Be in the USA
- 3 . Be fluent in English
- 4 . Have a high school degree or equivalent
- 5 . Use a desktop device to complete the survey (do not use mobile or tablet devices)

Devices you can use to take this study:

Desktop

Figure 30: Recruitment call displayed on Prolific crowd worker platform.