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A Custom Generative AI Chatbot as a Course Resource

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1 Abstract

Generative AI (GenAI) chatbots have taken the world by storm with their ability to summarize information and produce complex natural language responses. At the same time, the demand for computer science education has grown enormously.

We developed a custom GenAI chatbot and released it to over 700 students to assist with a course programming project. The tool was trained on the project specification, lecture content, lab materials, and past course forum posts relevant to the project. The course is a high-enrollment upper-level computer science elective at a large public research university. The project is a simple distributed system using processes, threads, and sockets. The goal of the tool was to provide an additional course resource that supplies valuable information to students comparable to advice they would receive from course instructors.

We measured the effectiveness of our tool with a student survey, evaluation by course instructors, and comparison with a state-of-the-art general purpose chatbot. The overall survey data indicated high rates of correctness and helpfulness in the Bot responses. We found that hallucination was not common, and most incorrect responses were identifiable by students. The Bot also performed better than general purpose bots for project-specific help.

Our experience can provide insights for faculty using GenAI to assist students in their courses. A customized chatbot can be helpful to students and augment traditional course resources.

2 Introduction and Related Work

Generative AI tools, such as ChatGPT [1], have become increasingly prevalent for students throughout the past year [2][3]. A study has shown that the use of ChatGPT in education has had a positive impact on students' learning and educators' teaching, with proper instruction and training [4]. A commercial example is Khanmigo [5], developed by Khan Academy using GPT-4, which offers personalized help for students. The benefits of such a tool in higher education include teaching assistance, research support, and enhanced human-computer interaction [6].

*equal contribution, name in alphabetical order

For instructors, understanding how students use AI tools is crucial for adapting course structures and accounting for the assistance these tools provide. Currently, the main resources students use for help with their assignments are office hours and course forums. However, a recent study suggests that time conflicts between staff and students' busy timetables and low efficiency of overwhelmed office hours are obstacles to student attendance [7]. Because of the constant availability of AI chatbots, they may be ideal candidates for supplementing course forums and office hours. However, while standard AI tools can help with understanding course content in general, they do not have specific knowledge of particular course assignments.

There are several notable concerns with the use of AI tools for education, including plagiarism [6]. Our customized chatbot aims not only to provide accurate responses, but also focuses on assisting students in the learning process, rather than facilitating plagiarism. Furthermore, hallucination (false or misleading responses) could impede student learning [8]. One of our primary goals is to quantify hallucination experienced by students and its impact on them.

2.1 Contributions

This paper explores the impact of a curriculum-specific customized chatbot on student experiences completing a programming assignment. Our research questions are:

RQ1: Can a customized GenAI chatbot be helpful to students as a course resource?

RQ2: Is hallucination a barrier to student learning?

RQ3: How do customized chatbot responses compare to a general purpose chatbot?

3 Methods

First, we describe the context in which our study took place, including the course and specific assignment. Then, we introduce the custom GenAI chatbot used in the study. In the remaining sections, we outline our survey, methods for evaluation by expert instructors, and methods for a case study comparison with an existing state-of-the-art general purpose chatbot (ChatGPT).

3.1 Course and project

Our study took place over the duration of one project in a high enrollment, upper-level programming course at a large public research university. The course focuses on web systems, including web apps and web distributed systems. Prerequisite courses include data structures and algorithms, programming (CS2), and discrete math. Some students may have taken other upper-level courses that exposed them to distributed systems and/or parallel programming before taking the course in our study. Most students in the course were juniors and seniors.

The project in our study is a distributed system where students implement a MapReduce framework using processes, threads, sockets, and basic parallel and networking programming techniques in Python. It is the fourth of five projects and is generally viewed as challenging by students. Most students worked in groups of 2-3.

3.2 Custom GenAI Chatbot

We created a custom, web-based GenAI chatbot. First, we used a custom dataset to build an index. At query time, the chatbot instance retrieves the most relevant documents, combines them with the user prompt, and sends them to a Large Language Model (LLM). Then, the response is returned to the user.

3.2.1 Bot model

Our chatbot is based on OpenAI's GPT-4 [1]. We created a vector model from the training documents using an embedding model tuned to work with GPT-4, provided by OpenAI.

When a user prompts the chatbot, the tool performs a similarity search over the training documents using the vector model. It selects up to 4 of the closest training documents and bundles them with the user's prompt as context (Figure 2). This bundled prompt is then sent to a dedicated instance of GPT-4 using the OpenAI API (Figure 1). This technique for bundling additional context with the user prompt is similar to using LangChain [9] with prompt templates.

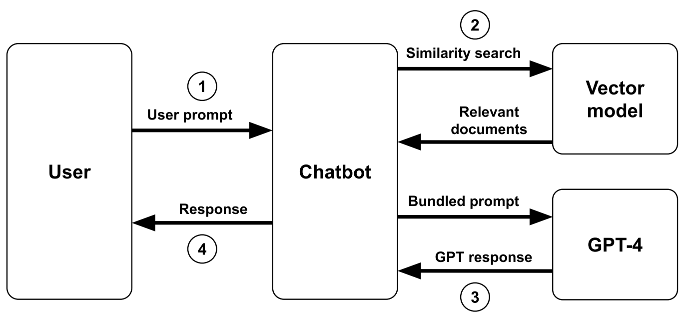


Figure 1: Bot architecture. The Bot searches relevant course materials, bundles the materials with the user prompt as context, and then sends the bundled prompt to GPT-4.

3.2.2 Training data

The Bot was trained on course materials relevant to the assignment in our study. Overall, there were 883 training documents, consisting of 185,429 tokens. Document indexing took about 8 minutes. The training documents consisted of 5 different types of course material available to all students:

- Project specification (HTML)
- 5 Instructor-written tutorials (HTML)
- Slides and transcripts from 4 relevant lectures (PDF, TXT)
- Slides from 2 relevant labs (PDF)
- Question-and-answer threads from relevant course forum posts over 3 semesters (TXT)

We restricted the range of course forum posts to only include those related to the assignment in our study. Each thread included a student question, instructor answer, student answer, and any follow up discussions, if available.

3.2.3 Configuration parameters

We tuned two important parameters: the system prompt and the temperature.

The system prompt defined how the Bot responded to users by creating a "persona," which we configured as a helpful teaching assistant. Figure 2 shows the system prompt, where *context* and *question* are replaced with the relevant training documents retrieved by the system and the user's original prompt, respectively.

> "Imagine you are a helpful teaching assistant for a web development course. Use the following pieces of context to answer the question at the end. If you don't know the answer, just say that you don't know, don't try to make up an answer. {*context*} Question: {*question*} Helpful Answer:"

Figure 2: The system prompt used by the Bot

The temperature affected the sensitivity and randomness of the model's output. Lower temperatures resulted in too many conservative responses, where the Bot was unsure and refused to answer the prompt. Higher temperatures resulted in answers that took too long to generate and did not follow English language conventions. We set the temperature to 1.2 (scale 0-2).

3.2.4 Student interface

We introduced students to the Bot in the project specification. The Bot was available for the duration of the two-and-a-half-week project. To manage expectations, we informed students that the Bot was experimental and may provide inaccurate or incomplete information.

The Bot had a ChatGPT-like interface for submitting prompts. Although students could prompt the Bot multiple times, the Bot was not conversational, meaning that students could not ask follow-up questions. Students could start multiple new chats and access their chat history.

3.3 Survey instrument

To collect data from each student group, we designed a survey that gathered information about their background, overall sentiment about the Bot, and interactions with the Bot in practice. The full survey is in Appendix A.

The background section included questions about student class standing and prior experience level with project topics (parallel and network programming).

The general section included questions about the helpfulness of the Bot, the number of interactions, its use instead of traditional course resources, and whether the Bot improved student coding performance and/or saved them time.

The final section requested 3 example interactions with the Bot. Each interaction included the student-provided prompt, the Bot response, and whether they thought the Bot's response was correct and/or helpful.

After collection, we filtered the surveys and interactions for empty or invalid submissions.

3.4 Evaluating hallucinations and helpfulness

To assess the rate of hallucination (false or misleading responses), we analyzed a subsample of interactions. We used the standard formula for calculating the sample size with a 5% margin of error, 95% confidence level, and conservative population proportion of 50%.

We grouped every interaction by the question categories presented to students in the survey (Table 2). A team of instructors evaluated each Bot response against the student prompt, marking it as correct and/or helpful. The instructors defined Bot "correctness" as whether the Bot gave a correct response considering the student's prompt in isolation, and Bot "helpfulness" as whether the response would help students make progress on the project and would be reasonable advice given by course staff. We then compared and measured the level of agreement between the expert instructor opinion and the student survey response for each interaction.

To understand perceptions of the Bot from different perspectives, we performed chi-square tests on contingency tables between student prior programming experience and whether the Bot helped save time, as well as with the number of interactions they had with the Bot.

3.5 Evaluating customization

We performed a qualitative comparison between our customized Bot and the general purpose chatbot ChatGPT Pro [1], which both use GPT-4. First, we compared the responses from the two tools using the exact same prompts. Second, we compared the tools when adding additional context to the prompt for ChatGPT Pro. Finally, we examined how well each tool performed across the different prompt categories taken from the student survey. The same team of instructors reviewed the responses for helpfulness.

4 Results

First, we provide a general summary of our survey data followed by overall student-reported perceptions of the Bot. Then, we examine the impact of hallucination by having a team of instructors review the Bot's responses. Finally, we compare the performance of our custom Bot with a state-of-the-art general purpose chatbot.

4.1 Summary statistics

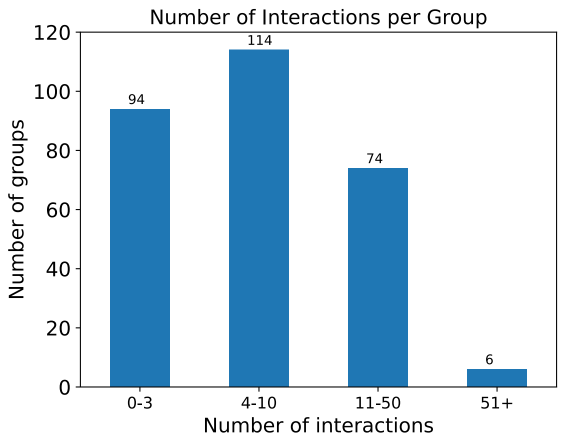
The data was collected at the end of the two-and-a-half-week project duration during the Fall 2023 semester, with a course enrollment of 703 students. Out of 294 surveys collected from student groups, 5 were empty. There were 48 invalid or empty interactions. After filtering, we had 289 valid survey responses containing 834 valid student-Bot interactions.

The majority of students had junior or senior standing. Even though the survey only required 3 interactions for credit, many student groups interacted with the Bot more than that, averaging 4-10 interactions (Figure 3a).

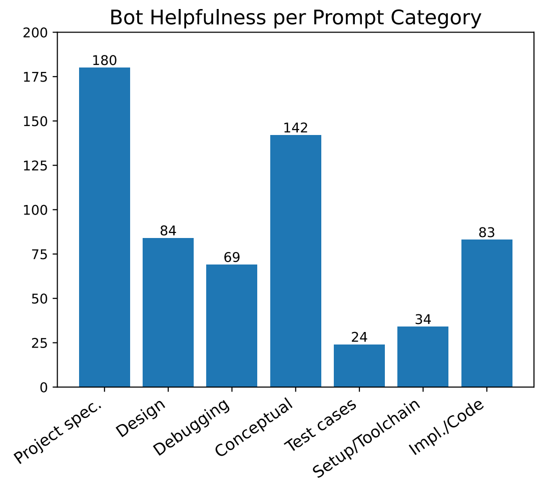
4.2 Bot helpfulness

Students indicated that 77.0% of interactions were helpful. 60.9% of survey responses said that a similar bot would be helpful for other projects, 8.65% disagreed, and the rest were unsure. Students reported that the Bot was most helpful for answering project specification and conceptual questions, and least helpful for explaining test cases (Figure 3b).

When asked if using the Bot instead of the course forum or office hours saved time, 40.1% of students answered yes, while 21.8% said no. 30.5% of students reported that using the Bot helped them code faster, while 36.7% disagreed. The rest of the responses were unsure.



(a) Number of interactions with the Bot for each student group. Most student groups used the Bot at least 4-10 times.



(b) Student-reported Bot helpfulness per prompt category. Students found the Bot to be most helpful for project specification questions.

Figure 3: Number of interactions with the Bot for each student group and per prompt category.

4.3 Comparison with course resources

Although some students used the Bot instead of the course forum and office hours, a majority indicated that they never or rarely used the Bot as an alternative to staff assistance (Figure 4). Overall, students were more likely to use the Bot instead of the course forum than instead of office hours.

4.4 Student prior experience

We conducted chi-square tests to examine the associations between several measures of student prior experience and their perceptions of the Bot (Table 1). We excluded "unsure" options and buckets with limited responses. There were no statistically significant associations.

4.5 Hallucinations and expert evaluations

Our Bot displayed low rates of hallucination and high rates of helpfulness across the subsample of 263 interactions reviewed by instructors (described in Section 3.4).

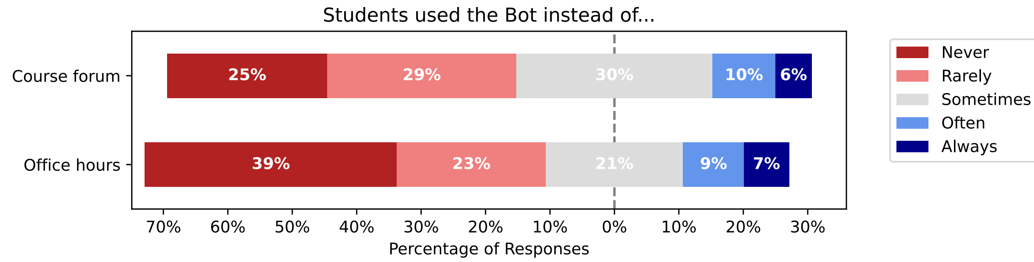


Figure 4: Comparison of Bot usage with traditional course resources. Most students still preferred interacting with instructors in office hours or on the course forum, suggesting that the Bot may augment, but not replace, traditional course resources.

Independent and dependent variables	***p*-value**	**χ^2 statistic**	***df***
Parallel programming experience and the Bot saved time	0.095	2.78	1
Network programming experience and the Bot saved time	0.055	3.68	1
Parallel programming experience and number of interactions	0.101	4.58	2
Network programming experience and number of interactions	0.076	5.15	2
Class standing and the Bot saved time	0.648	5.99	8
Class standing and number of interactions	0.266	9.99	8

Table 1: Chi-square test results analyzing the association between measures of prior experience and perceptions of the Bot. We did not observe any statistically significant associations ($p < 0.05$).

92.0% of Bot responses were correct based on instructor review. Of the 8.0% incorrect responses, students correctly identified 96.3% as incorrect. Of the 27.4% of interactions that were marked as incorrect by students, 80.6% of responses were actually correct after review.

84.8% of Bot responses were helpful for assignment progress based on expert review. Of the 15.2% of unhelpful responses, students agreed with the experts 94.2% of the time. Of the 28.1% of interactions that were marked as unhelpful by students, 60.8% were actually helpful after review.

Within the prompt categories, most student prompts were implementation questions or requests for code suggestions (Table 2). The Bot had the highest rate of correctness for debugging questions and the highest rate of helpfulness for conceptual questions (questions related to general coding concepts not specific to the assignment). In almost all categories, the Bot was more correct than it was helpful. The only exception to this was the "Setup/Toolchain" category, where all correct responses were also helpful.

4.6 Customized vs. general purpose chatbot

We found that a customized Bot has advantages over general purpose chatbots, like ChatGPT. In this section, we highlight some of the qualitative differences.

First, we queried our Bot and ChatGPT with a several student prompts from the survey. A common prompt was asking for tips on starting the project. For example, in response to the student prompt "How should I start the project?", our Bot provided a highly detailed response, telling students to read the relevant course materials and suggested an order of implementation,

Prompt Category	**N**	**Correct**	**Helpful**
Project specification	38	94.7%	86.8%
Design	49	87.8%	79.6%
Debugging	30	100%	90.0%
Conceptual	36	97.2%	91.7%
Explaining test cases	15	80.0%	73.3%
Setup/Toolchain	5	80.0%	80.0%
Implementation/Code suggestions	68	92.7%	86.8%

Table 2: Bot correctness and helpfulness based on expert review, divided by category. The Bot produced the most correct responses for debugging questions and the most helpful responses for conceptual questions. It was the least helpful for explaining test cases.

including specific references to the project specification. ChatGPT responded with a very generic list of steps for how to start a project, which was irrelevant to the course project and programming projects in general. The full example prompt and responses are in Appendix B.

Another representative prompt from our survey was more specific to the project, "What should program behavior be if no jobs are left to complete?" Our Bot provided a clear answer aligned with the project specification, while ChatGPT did not. To try to elicit a more detailed response from ChatGPT, we mimicked what a student familiar with general purpose chatbots might do and provided additional context copied from approximately half of the project specification. After including this information, the response discussed different design decisions, but was too vague, unhelpful, and still didn't take the specific project requirements into consideration.

Finally, we divided prompts by category using the taxonomy from the student survey. We queried both our custom Bot and ChatGPT using several student prompts from each category, providing ChatGPT with additional context from the project specification as needed. The team of instructors rated the responses from each chatbot for overall helpfulness in each category (Table 3).

Prompt Category	**Our Bot**	**ChatGPT**
Project specification	✓	×
Design	✓	×
Debugging	✓	✓
Conceptual	✓	✓
Explaining test cases	✓	×
Setup/Toolchain	✓	✓
Implementation/Code suggestions	✓	*

✓	Helpful responses
×	Unhelpful responses
*	Helpful for general prompts, unhelpful for project-specific prompts

Table 3: Bot vs. ChatGPT helpfulness divided by category. The Bot performed well in all categories, while ChatGPT gave helpful responses for general categories but not project-specific ones.

5 Discussion

Students found the customized chatbot helpful as a supplement to existing course resources (RQ1). The Bot was good at summarizing information and hallucination was not a barrier to student learning (RQ2). The concentrated scope of the Bot had advantages over general purpose chatbots (RQ3). Students found the Bot most helpful with project specification and conceptual questions. Student expectations of the Bot affected their evaluations of its helpfulness.

5.1 Hallucination was not a barrier to student learning

The Bot provided correct responses 92% of the time, according to the expert instructor review. Of the incorrect responses, students correctly identified 96% of them. These results suggest that hallucination was not a widespread barrier to student learning.

Students may have been skeptical of the Bot and more likely to report its correctness conservatively. Most responses that students marked as incorrect were correct upon instructor review. Possible reasons for this include students' incomplete understanding of the assignment and a lack of trust in Bot responses.

85% of the sample responses were helpful for completing the assignment upon instructor review. Of the unhelpful responses, students agreed with the instructor opinion 94% of the time. This corroborates the insight that students can reliably spot when a response is not helpful.

Unhelpful responses were not always hallucinations. The Bot tended to be more correct than helpful for completing the assignment. The rate of correct responses was strictly larger than the rate of helpful responses in 6 of the 7 prompt categories. While the Bot had a low hallucination rate overall, there were some interactions where the correct response was not targeted enough to help students make progress on the assignment.

5.2 Concentrated scope supports student learning

The key to our custom Bot was its concentrated scope. The focused training data allowed our Bot to give useful, detailed responses about the course project. GenAI excels at generating concise summaries of longer texts with a simple prompt [10]. Our custom Bot performed exceptionally well at summarizing assignment resources in its responses.

Our Bot had a high rate of helpfulness for high-level conceptual questions. For prompts like "Explain threads and sockets to me," both ChatGPT and the Bot gave correct, detailed responses, but the Bot focused on examples that were directly relevant to the project. Based on the qualitative analysis of the responses from our custom Bot and ChatGPT, using a focused chatbot was more beneficial than a general purpose chatbot in the context of a specific course project.

5.3 Student expectations of Bot helpfulness

Student evaluations of the Bot's helpfulness may reflect expectations of the Bot. A majority of student-reported unhelpful interactions were marked as helpful upon instructor review.

When Bot responses did not contain exact implementation steps or code, some students marked them as unhelpful, suggesting that students expected code rather than guidance similar to traditional instructor help.

Other students marked responses as unhelpful due to low-quality prompts. Some student prompts were too vague or obscure for the Bot to give a meaningful response. During office hours and on course forums, instructors can ask clarifying questions to gather enough information from students before responding, but the Bot could not provide the same interactive nature.

Most students still preferred interacting with instructors. More than half of student groups never or rarely used the Bot as a replacement for office hours and course forums (Figure 4). This may indicate higher levels of trust in traditional course resources at the time of this study.

5.4 Limitations

Students were required to fill out the survey, and we observed that some students did not fill it out properly and conscientiously. We filtered these out. Furthermore, the influence of completion credit for students may have impacted the sincerity of their responses, due to demand bias. Additionally, our survey asked each student group to report only 3 interactions, which may not have been a representative sample. For comparative survey questions like "Did responses help you code faster?", students self-reported without a baseline, reducing the validity of responses to these questions.

Another limitation was the lack of conversational responses from the Bot due to software constraints. The quality of responses may not have matched those from a conversational chatbot that uses previous prompts and responses as additional context. The Bot also did not support indexing code files for training data, limiting its knowledge to instructor-written materials.

Finally, the scope of this research is confined to one project within a specific upper-level course which may restrict the generalizability of our findings to other courses.

6 Conclusions and future work

We deployed a custom GenAI chatbot to assist with a distributed systems project for over 700 students in an upper-level course. The Bot was trained on the project specification, lecture content, lab materials, and past course forum posts. We aimed to evaluate if a GenAI tool could be a valuable addition to traditional course resources.

We found that the customized Bot provided overall helpful and correct responses. In addition to existing course resources, the Bot was helpful in assisting students with the project (RQ1). Hallucination was rare and instances were easily identifiable by students; therefore, it was not a barrier to student learning (RQ2). Our Bot had advantages over general purpose chatbots due to its concentrated scope (RQ3). Our results can provide insights for faculty considering GenAI as a course resource, particularly about the value of a customized chatbot.

Future work could include deploying a similar custom bot for courses covering different and/or more introductory programming concepts. Analysis of survey data and sample interactions could show differences in the usefulness of a custom bot with other student populations and other types of course assignments. Additionally, a future study could deploy an improved chatbot with more features, such as conversational responses or contextual search over different types of documents, such as the project starter files or test case source code. This could make the responses more targeted and helpful for questions specifically about explaining code or test cases, further augmenting the student experience.

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Appendix A: Survey Questions

Background

How many group members are:

- Grad students? **[0-3]**
- Senior standing or above? **[0-3]**
- Junior standing? **[0-3]**
- Sophomore standing? **[0-3]**
- Freshman standing? **[0-3]**

At least one group member had prior experience with parallel programming. **[Yes / No]**

At least one group member had prior experience with network programming. **[Yes / No]**

General

Did responses help you code faster? **[Yes / No / I don't know]**

Did using the Bot save you time waiting for staff help? **[Yes / No / I don't know]**

Approximately how many interactions did you have with the bot on project 4? **[0-3 / 4-10 / 11-50 / 51+]**

Check off the topics the bot was helpful with:

- Spec questions
- Design
- Debugging
- Conceptual questions
- Explaining test cases
- Setup/toolchain
- Implementation/code suggestions

Would a similar bot be helpful for other projects? **[Yes / No / I don't know]**

I used the bot instead of posting on Piazza: **[Never / Rarely / Sometimes / Often / Always]**

I used the bot instead of going to Office Hours: **[Never / Rarely / Sometimes / Often / Always]**

Using the bot instead of Piazza or Office Hours saved time: **[Yes / No / I don't know]**

Interaction

Prompt:

Response:

Was this response helpful? **[Yes / No]**

To the best of your knowledge, did it answer your question correctly? **[Yes / No / I don't know]**

NOTE: There were 3 identical interaction sections.

Appendix B: Prompt and Response Example

Prompt: how should I start the project?

Custom Bot Response: The best way to start the project is to break everything down into smaller, manageable parts. Before even starting, ensure a comfortable understanding of threads and sockets, by utilizing resources such as tutorials and articles. Make sure to revisit the project specifications multiple times, understanding the overarching structure and then processing the individual components involved. You could draft a development plan including every major step. Start with establishing communication between Manager and the Workers via sockets. Then, build upon this facility while keeping in mind the need for infrastructure to work on your other tasks seamlessly. Mastering modularity and sticking to good design principles like SOLID and DRY could enable you to successfully earmark the fault tolerance feature for the last phase of your project. Start the project in the exact order that components have been described in the ”MapReduce server specification” section, getting started with aspects the Manager and Worker have to undertake as soon as they’re initiated, would help lay down an indispensable network, facilitating your overall project progression. This ultimately reinforces the concept of starting with the implementation of a socket infrastructure.

ChatGPT* Response: Starting a project can be an exciting but challenging endeavor. Here are some general steps to help you get started:

- Define the Project Goal: Clearly articulate what you want to achieve. This could be solving a problem, creating something new, or improving an existing process or product.
- Research: Gather information about similar projects, understand the current state of the field, and identify best practices. This will help you avoid common pitfalls and leverage successful strategies.
- Plan Your Approach: Break down the project into smaller, manageable tasks. Decide on the methodologies, tools, and resources you will need. This could involve choosing technologies for a tech project, outlining chapters for a book, or sketching designs for a product.
- Set a Timeline: Establish a realistic timeline with specific milestones. This will keep the project on track and help in measuring progress.
- Budgeting: If applicable, create a budget. Consider costs for materials, software, labor, or any other resources you’ll need.
- Assemble a Team: If your project requires a team, carefully select individuals with the necessary skills and experience. Clearly define roles and responsibilities.
- Risk Assessment: Identify potential challenges or risks and plan how to mitigate them. This could include technical difficulties, funding shortfalls, or market changes.
- Start Small: Begin with a prototype, pilot, or draft to test your ideas. This allows you to make adjustments early based on feedback.
- Iterate and Improve: Continuously evaluate progress, gather feedback, and refine your approach. Be flexible and open to making changes.
- Document Everything: Keep detailed records of your process, decisions, and modifications. This is crucial for tracking progress and can be invaluable for future projects or audits.
- Stay Motivated and Organized: Keep your goal in mind and maintain a positive attitude. Use tools and techniques to stay organized, such as project management software or a well-structured filing system.
- Communicate Effectively: Whether working alone or in a team, clear communication is key. Regular updates, meetings, or reports can help everyone stay on the same page.
- Remember, the specific steps can vary depending on the nature of your project. Whether it’s a research project, a software development task, a creative endeavor, or something else, tailor these steps to fit your specific needs.

*ChatGPT was not provided with any additional context.