Quantaide: AI based quantitative research assistant

Master of Information Management and Systems
Final Project Report

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1. Introduction

Quantaide is an AI-powered learning platform designed to assist users in research methodology and survey design. Quantaide enables users to craft precise and impactful surveys tailored to their specific needs, by harnessing AI guidance. Through accessible learning modules and insightful evaluations, users are empowered to navigate the complexities of research methodology with confidence.

Quantaide tailors the learning experience to the user's domain of interest, providing guided modules that ensure active participation while maintaining the user's autonomy. With Quantaide, users can create surveys that yield meaningful insights, all while benefiting from AI support without relinquishing control of the research process.

In an era where data-driven decision-making is paramount, Quantaide emerges as a valuable tool for researchers, entrepreneurs, educators, and professionals across various industries, with or without prior experience in research methodology. By democratizing access to research methodology expertise and streamlining the survey design process, Quantaide empowers users to leverage the power of data in their endeavors. Whether it's validating business ideas, conducting academic research, or optimizing product development, Quantaide equips users with the knowledge and tools needed to navigate the complexities of research with ease. With its intuitive interface, personalized learning experience, and AI-guided support, Quantaide revolutionizes the way research is conducted, making it accessible, efficient, and impactful for users of all backgrounds and expertise levels.

2. Our Vision

At Quantaide, we're dedicated to fostering a data-centric mindset among individuals from all walks of life. We firmly believe that everyone, regardless of their field, can unlock greater potential when they have the means to gather valuable insights from their target audience. That's why we've developed Quantaide—to democratize access to research methodology expertise.

3. Target Audience and Potential Users

The ideal target audience for Quantaide encompasses individuals from various backgrounds aiming to deepen their grasp of quantitative research methods and survey design, irrespective of their STEM proficiency. It serves as a valuable resource for anyone requiring a platform not just for crafting customized surveys but also for assimilating and employing scientific methodologies throughout their research journey. Our users range from those with technical backgrounds and prior research experience seeking guidance on applying these concepts to their unique use cases to individuals intimidated by the complexities of research design.

We have listed below some of the user personas that we drafted during our research:

Entrepreneurial Emily

- **Background**: Emily is a passionate entrepreneur developing a music app aimed at alleviating insomnia.
- **Goals**: Emily aims to gather insights on sleep patterns and preferences to understand market fit and enhance her app's effectiveness in promoting relaxation and better sleep.
- **Challenges**: Limited knowledge in research methodology and survey design, along with the need to validate her app's features and gather user feedback.
- **Needs**: Emily requires a platform that offers accessible resources for learning about research methods and guidance in crafting surveys tailored to sleep-related issues.
- **Expectations**: Emily expects Quantaide to provide user-friendly interfaces for survey creation and AI-assisted evaluation to ensure survey accuracy to improve her app's functionality.

Student Sameer

- **Background**: Sam is a university student majoring in social sciences, with limited experience in quantitative research.
- **Goals**: Sam wants to conduct research projects for his thesis work.
- **Challenges**: Lack of experience in research methodology and survey design, along with the pressure to produce high-quality research.
- **Needs**: Sam needs a platform that offers comprehensive learning materials, step-by-step guidance in survey creation, and tools for data analysis.
- **Expectations**: Sam expects Quantaide to provide educational content aligned with academic requirements, be different from MOOCs as he does not have the time for it, and intuitive survey design features.

Teaching Thomas

- **Background**: Thomas is a professor of a psychology elective course.
- **Goals**: Thomas aims to introduce his students to research methodology and engage them in conducting their own studies on topics related to various fields of their interest.
- **Challenges**: Limited time and resources for teaching research methods effectively, he struggles to find diverse examples that would cater to the interests of his students.
- **Needs**: Thomas requires a platform that offers structured lesson plans on research methodology, topic specific survey designs to ensure student engagement, and tools for evaluating student learnings.
- **Expectations**: Thomas expects Quantaide to provide ready-to-use teaching materials, options for customizing survey design assistant to a specific interest, and features for tracking student evaluation and learning.

Healthcare Professional Heena

- **Background**: Heena specializes in sleep medicine at an NGO.
- **Goals**: Heena aims to conduct patient surveys to assess sleep quality and identify factors contributing to sleep disorders.
- **Challenges**: Heena needs to make sure she is compliant with laws while creating surveys for patients.

- **Needs**: Heena requires a platform that offers a tool for survey creation and gives options for her to add relevant documents to ensure that she securely collects and analyzes patient data.
- **Expectations**: Heena expects Quantaide to provide functionality that looks at her documents and makes sure she is compliant with concerned laws which assist her with the survey design.

4. Background Research

4.1 Existing Products

With the demand for data and data driven solutions increasing, we wanted to build a product that is innovative. We researched existing products, analyzed academic literature, and used our direct experience.

At the moment there are no products that help users learn quantitative research, but there are a few products for other types of analysis that are starting to use AI. These products include Amazon SageMaker and DataRobot. These products are designed to help users clean data, create machine learning models, deploy models, and give insight into machine learning findings. These platforms use AI to help users quickly clean and prepare data, help choose models, and tune them. The most interesting aspect of these platforms is that they also have some ability to give insight into the findings that were created through machine learning which helps users understand the implications of the models on their business. Furthermore, both SageMaker and DataRobot leverage AI to empower users to accomplish tasks with greater automation and minimal manual intervention.

There are also products like SurveyMonkey, Qualtrics, and Google Forms. SurveyMonkey and Quantrics are popular platforms to use when conducting quantitative research. These platforms allow users to create surveys, deploy surveys en masse, and analyze data. Recently, Quantrics has made advances as it has implemented AI into their product to help the user analyze data and create predictive models. Additionally, with the integration of AI, Qualtrics does a lot of the analysis and predictive analytics for the user which limits the understanding and involvement of the user. Google Forms is another platform that can be used to conduct quantitative research. Google Forms is a simple survey tool that can be sent to anyone and is the easiest to access for most people starting quantitative research. Like the other platforms, Google Forms does not help the user understand quantitative research and the methods needed to conduct it.

4.2 Product Insights gained from Existing Products

While we were intrigued with Amazon SageMaker and DataRobot and especially the feedback systems, we wanted to create a product that also has AI capabilities but is used to learn quantitative research. Since we were making an educational tool, we wanted to ensure that our tool is keeping the human in the loop and that AI is not doing everything for the user, other than acting as a guide.

We are very intrigued by the capabilities of Survey Monkey, Qualtrics, and Google Forms since they can be used for quantitative research, but we want to create a product that is more focused on helping users learn quantitative research. These platforms do not teach the user how to create research questions, hypotheses, or

even how to create good survey questions. In order to use these three platforms, one must already have knowledge of quantitative research.

4.2 Existing Literature

AI has become a staple in everyday life and has the potential to greatly impact education and research. According to Alqahtani et al (2023), AI is transforming education through personalized learning and helping instructors with grading. In terms of personalized learning, AI can help create personalized learning for students, develop personalized feedback, and develop adaptive learning systems. In terms of grading, AI can help instructors save time grading with AI assistance instead of manually grading, can reduce subjectivity and bias, and provide instant feedback and grading. This paper mentions the application of AI and NLP with automated short answer grading (ASAG) which is short answers that are evaluated by machine learning. Towards the end of the paper, they mention how AI is helping with literature reviews and enhancing peer review through AI. This paper also mentions how AI is useful in assisting in data analysis and interpretation. This paper concludes with mentioning that AI has great potential to help in the educational sector but it also must be carefully managed. At the moment, a combination of AI and human support is the best way to integrate AI and we wholeheartedly agree which is why our product is aimed at being human in the loop.

Are AI tools actually helping boost student learning outcomes? According to Boubker (2024), AI tools have gained popularity and the potential to be applied to a wide range of educational tools. Boubker puts a heavy emphasis on the personalization of feedback and experiences through using AI and specifically ChatGPT. This study investigates the impact of ChatGPT on students' learning outcomes by collecting data about output quality, social influence, perceived usefulness, perceived ease of use, ChatGPT usage, student satisfaction, and individual impact. Boubker's findings include that output quality of ChatGPT influences perceived usefulness, ChatGPT usage, and student satisfaction. There are limitations to this study as it only sampled students from Moroccan higher education and it ignores the professors' attitudes towards ChatGPT which may have an influence on how students perceive it. This study finishes by mentioning that AI tools can be beneficial to higher education but also should be noted that there are challenges to implementing these tools. Tools like ChatGPT can be considered disruptive tools and using tools that are less engulfing can be beneficial to students learning new material.

4.4 Product Insights gained from Existing Literature

According to Alqahtani et al. (2023), the application of AI in education has many benefits for students and faculty but must be carefully managed as this is a new technology. Since we are interested in building an AI educational tool, we are very intrigued in the application of AI for personalized feedback and grading. Alqahtani et al. do not mention the specific use of AI in the field of quantitative research, so we have engineered a feedback system using RAG to provide the user with instant feedback in Quantaide. Alqahtani et al. mentioned the use of automated short answer grading (ASAG), but does not give a real example of this technology. In Quantaide we are curious about evaluating short answers about specific topics like hypotheses or problem statements. In addition, our product has a grading mechanism in which we use cosine similarity and baseline sentences to compare user inputs against in order to see how similar user input sentences are to the ideal baseline sentences. AI is helping with literature reviews and enhancing peer review but this is a very niche part of academia. When we originally envisioned our product, we viewed our product as an alternative to

getting peer feedback for their learnings in quantitative research. Our tool will take the place of a classmate or professor who normally would have to manually evaluate the user's quantitative research design. Lastly, regarding AI data visualizations, we find this field of research intriguing and see it as a potential avenue for our future endeavors post-graduation. This paper has helped us identify ways to build our product and identified ways for us to improve our models that we have created.

According to Boubker (2024), AI tools have gained popularity and the potential to be applied to a wide range of educational tools. With this in mind, when building an AI tool for students to learn from, output quality in the form of feedback needs to be precise and accurate. Boubker does not mention any other tools besides ChatGPT, so we are curious if this also applies to other uses of AI tools. Quality feedback will be important on whether users of our product perceive our tool as useful and are satisfied with it. Boubker mentions how ChatGPT can be considered a disruptive tool and how less engulfing tools can be beneficial for student learning. This is why we are interested in building a human in the loop tool so students cannot purely rely on AI to do their work but to actually interact with AI through our tool to better understand the material being presented.

4.5 Direct Experience

4.5.1 GSI Experience

Quantaide was initially conceived based on Chandramita's experience as Graduate Student Instructor for the course "Psych 101: Research Design and Data Analysis," an undergraduate course focused on research design. The students, primarily first-year undergraduates with a psychology background, encounter this subject for the first time. Through this experience, she recognized the steep learning curve associated with grasping the fundamentals and concepts of research. The final project in the course entails survey design, where students are tasked with conducting research in their domain of interest. She identified a gap wherein, despite understanding the concepts, students found building domain-specific surveys challenging. Moreover, the limited resources of the teaching team made it challenging to address each student's unique queries effectively.

4.5.2 D-Lab Experience

While working as a Consultant at the Berkeley D-Lab, Chirag noticed that many students, researchers, and professors across departments were seeking to gather real-world data for their projects or work. They needed assistance, both technical and conceptual, with designing surveys and implementing best practices for running experiments. While they were aware of tools like Google Forms and Survey Monkey, they lacked clarity on how to design survey questions effectively. Additionally, they were uncertain whether using a template for the questions would result in data that was as useful or impactful as they desired. Quantaide's concept addresses the needs of such individuals. It offers a solution to quickly understand the survey design process through concise, easy-to-follow modules. Furthermore, it provides real-time feedback on the quality of each question.

5. Summing it all up: Introducing Quantaide

Quantaide is currently available as a web based application. It has six learning modules which take the user through Problem Statement, Justification, Argument, Hypothesis, Research Question, and lastly Question Formulation, where they design a survey. On each of these modules, users are evaluated on their learnings

through one or more questions and are given a score ranging from 1-5 based on its similarity to the benchmark. One of the unique features of Quantaide is that users can add texts and upload any number of documents to train the tool to understand their area of interest. This makes the whole user experience personalized. The design philosophy behind the tool is human centered so that we ensure the user still learns and takes all the decisions about their survey on their own, despite having AI as an assistant. Lastly, the evaluation feature makes sure users have enough feedback to improve their responses, and the AI suggestions show them options on how to improve.

6. Development

6.1 Design

Quantaide, primarily a learning platform, embodies several key design principles to ensure functionality, usability, and accessibility. It was essential to place the human at the center of the design process and ensure that our platform meets their needs and preferences by understanding user personas, their goals, and pain points. The design prioritizes HCI principles to ensure that users can easily navigate through the platform, access learning materials, and interact with AI-guided features such as suggestions. Emphasis is placed on intuitive and accessible interfaces, clear feedback mechanisms, and seamless interactions to enhance the user experience. Learning materials in each module are structured in a way that is easily digestible to facilitate understanding and retention by organizing content logically with explanations, examples, and interactive testing to engage users and support active learning.

Quantaide offers customized learning paths, suggestions, and feedback mechanisms that adapt to individual preferences and progress, promoting effective learning. This is reinforced with a user input mechanism where users are prompted to type in problem statements, research questions, and hypotheses, which are then evaluated and given feedback. The feedback mechanism provides users with timely, relevant feedback through AI-guided evaluations, scoring systems, and suggestions for improvement to help users track their learning journey and make informed adjustments.

The visual design of Quantaide focuses on clarity, consistency, and accessibility. The user interface is designed with clean layouts, intuitive navigation within and between modules, and visually appealing elements that enhance usability and engagement.

By integrating these design principles and considerations, Quantaide aims to provide users with a seamless, engaging, and impactful learning experience in quantitative research methodology and survey design.

6.2 Backend

Quantaide harnesses the sophisticated capabilities of RAG-enabled LLMs, specifically GPT-4.0-turbo, to provide precise, knowledge-aligned recommendations throughout the survey creation process, from initial problem formulation to nuanced question framing. This process is significantly enhanced by advanced prompt engineering, which fine-tunes the model's responses to deliver highly relevant and impactful suggestions, ensuring they are both precise and effective. The integration of OpenAI's vector stores and Assistants API

allows the system to analyze uploaded conceptual data, enabling the generation of customized recommendations tailored to user-specific needs. Users also have the option to upload their own field-specific data, which further refines the model's ability to provide personalized guidance.

This technology is a central module of the entire project, pivotal in facilitating users, even those without expertise in survey design, to effectively generate surveys that are meticulously aligned with their objectives. Hosted on Google Cloud Platform and streamlined through an HTTP API, the system employs serverless technology for robust deployment and efficient monitoring. This setup not only augments user input but guides them to the optimal survey design, enhancing decision-making and ensuring they land precisely where needed. This integration of cutting-edge technology and user-centered design is what makes Quantaide a groundbreaking tool in survey creation.

6.3 Front End and UI

Quantaide leverages the robustness of Next.js for seamless server-side rendering and client site generation, ensuring fast load times and improved SEO. The frontend showcases a modern aesthetic with Tailwind CSS for intuitive, responsive design, all hosted on Vercel for effortless deployment and scalability. For data and state management, we used MongoDB due to flexible data types of the form elements to fit the application's needs.

However, it was not without its challenges. Building a fully functional dynamic website and integrating it with a retrieval-augmented generation (RAG) agent on the backend presented particular complexities. Overcoming these hurdles allowed us to create an app that provides users with real-time feedback on their progress, enhancing their overall experience.

6.4 User Input Evaluation Method

Since we wanted to have an evaluation of user inputs as part of our product, we decided that we need to come up with a way to evaluate sentences. When researching models, we found cosine similarity which provides a value between zero and one that defines the similarity between two pieces of text data.

When we started to build our evaluation system, we had to decide what other piece of text we would compare the user input with. In order to find some ground truth for the answer that we are looking for, we used information from INFO 271B (Quantitative Research Methods for Information Systems and Management) and *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* by John Creswell. By creating a solid ground truth of what a good response to our question is, we can then compare user inputs against it to see if it is similar.

Our first iteration of our evaluation model was created using the ntlk library along with sklearn. We created a function to tokenize, remove stopwords, and lemmatize the text then input those variables into TfidfVectorizer. Once we had this, we then calculated cosine similarity. Our results from this model worked well with some input sentences and not as well with other input sentences. The model did not seem to make a clear distinction between sentences that were similar and sentences that were less similar. The values it output were not very different. As a follow up to this initial mode, we then added additional features to our model such as synonyms, but this did not lead to any significant improvements in our model.

Not satisfied with our model, we decided to incorporate transformer architecture by using BERT (Bidirectional Encoder Representations from Transformers) models. We used BERT base, tokenized sentences, then using PyTorch and BERT base we calculated the cosine similarity. Immediately our model was much better than the original model and it was doing a better job at determining similar sentences versus non-similar sentences. With this in mind, we decided that one baseline sentence would not be enough to compare user inputs against so we adjusted our code to take in a list of sentences and iterate through all of them. We then decided to take the max cosine similarity value when comparing the user input sentence against each of the baseline sentences. This would indicate to us how close the closest baseline sentence is to the user input sentence.

Now that we had our evaluation model outputting the values that we wanted, we then had to decide how to determine what values constitute a good input sentence versus a bad input sentence. After meticulously testing different input sentences, we decided that anything above a .9 in cosine similarity score would receive a five out of 5 stars. Anything between .8-.9 is four stars, .7-.8 is 3 stars, .6-.7 is 2 stars, and anything below .6 is 1 star.

Once we had the basic framework for our evaluation model, we used more material from INFO 271B (Quantitative Research Methods for Information Systems and Management) and *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* by John Creswell to create baseline sentences for each place where a user would input an answer in our product. For example, if the user is prompted to input a hypothesis about music and mental health, we created 6 baseline hypotheses for the user input to compare against. We did our best to make these baseline sentences as straightforward, correct, and also diverse to cover a wide range of possible input sentences. In addition to handcrafting baseline sentences for the user input to compare against, we also prompted our GPT with additional documents from the user to output five more baseline sentences to make the sum of baseline sentences for each user input to be 10 total.

We also want to consider the impact that AI feedback has on users in terms of learning how to create effective quantitative research. When putting the user input into the cosine similarity evaluation model, we get a value from 0-1. The GPT recommendations given to users after they input their own answers are also run through the same cosine similarity model and given scores. Depending on which recommendation the users picks, we will then take the delta between cosine similarity scores from user input and the GPT generated recommendation they picked. Since we have multiple human in the loop features where users input their answers, we collected data from user testing and compiled the data. Once we had this compiled data, we then created a Tableau chart (see Figure 1 in the appendix) to help us visualize the effectiveness and utility of our AI engine to cater to the needs of our users.

7. User Testing

7.1 Feedback

Once we had created a minimum viable product, we then decided to begin user testing to get feedback on the design, usability, and evaluation. Within the design, we got positive feedback for the sidebar and the star system feedback, but slightly negative feedback for the file upload button. Users understood that the ‘plus’ button was used to upload files but they also mentioned that a different shape or icon would be more intuitive

for the user. Within usability, we got positive feedback on the simple to use buttons and examples of concepts but negative feedback on confusing content and text color. Buttons which helped users progress through the app were easily understandable and the examples of problem statements helps users understand what is required in a good problems statement. We also got some feedback asking for an example of what a bad problem statement or what bad wording is. Some content was also believed to be confusing as prompts were sometimes misleading users. In addition, text color was a major issue because users could not tell if a text box was filled in since the color did not change from gray to black. For the evaluation, users had a difficult time understanding how to further improve their answers if they got a 4 out of 5 stars. The AI would respond with positive feedback but those looking for a 5 out of 5 stars would not have the required feedback for further improvement.

7.2 Implementation

With this feedback in mind, we set out to improve Quantaide. We started by fixing the upload document button. We then fixed the content on the pages to be more intuitive and clearly worded. We did this by rewording the instructions for user inputs in module 6. Lastly, we adjusted the CSS code to change the text color of the user inputs in module 6 to help the user better identify what they wrote.

8. Discussion

8.1 Successes

Throughout this whole process, we were able to create an educational AI tool that is able to help students learn quantitative research. As we dove deeper into the world of quantitative research and heard about the importance of this skill in the workforce, we were confident that we had picked the right topic for our project. We were successful in our implementation of AI for giving feedback for user inputs and when creating an evaluation system using NLP for user inputs. We successfully created content that was easy to understand for new learners and designed an effective tool for users to navigate through.

8.2 Challenges

During this process, we also had quite a few challenges which include adjusting the scope of our project, technical challenges, and reallocation of team members.

At the start of our project ideation, we wanted to build a fully functional AI tool that helped users conduct quantitative research from research question conception to data visualization. We researched existing products and innovations in AI and quickly realized that creating data visualization through AI was already on the market. We then began to create low fidelity screens to visualize the tool that we wanted to build. After our initial few meetings with Professor Cheshire, we realized that we needed to reduce the scope of our project if we were to successfully complete the main part of the project which is to create an AI educational tool to help users learn quantitative research. We reduced our work to only include the creation of research questions to survey creation and eliminated the goal of AI data visualization and dummy data creation for preliminary data analysis.

In terms of technical challenges, we ran into a few on the data science side. When researching what types of NLP models we could use to evaluate sentences, we ran into the issue of not being able to find anything that could successfully do it. We were looking for the model to output a single value that we could use to turn into a visualization of 1 to 5 stars depending on the value. We looked around at different Huggingface models but many of the models were evaluating the output of different text generating algorithms which did not apply to us. We then decided to use the simpler model of cosine similarity and to create ideal baseline text to compare user inputs against.

As the scope of our project changed, so did the tasks needed to complete the project. Our project began to stray further from data science and AI to mostly engineering and design. With this in mind, we had to redistribute many of the tasks to ensure everyone was able to get the required work completed.

Lastly, we had challenges designing the system in a way that is user friendly while also ensuring that Quantaide is a human in the loop tool. Creating places for users to be engaged with the content was challenging, but we tackled this by allowing for user input followed by personalized feedback. Finding ways to make Quantaide user friendly was also a challenge, but through user testing we were able to get a better understanding of how users navigate Quantaide. Through testing, we learned about the ways that Quantaide is less user friendly and used that knowledge to improve Quantaide.

9. Future Work

We envision Quantaide as the quintessential learning platform for users embracing a data-driven approach to delve deeper into their domains of interest through quantitative research. We foresee four key areas for expansion:

Analysis Module:
Incorporating a robust and user-friendly analysis module will enable users to derive comprehensive insights from their research data. Statistical analysis tools will facilitate hypothesis testing and decision-making, complementing Quantaide's user-friendly and human-in-the-loop system, particularly beneficial for non-STEM users.

Learning Modules Enhancement:
Expanding beyond survey design, future iterations will enrich the learning modules with advanced concepts and edge cases, ensuring users attain a deeper understanding of research methodology. Continuous refinement based on user feedback will ensure an efficient learning experience.

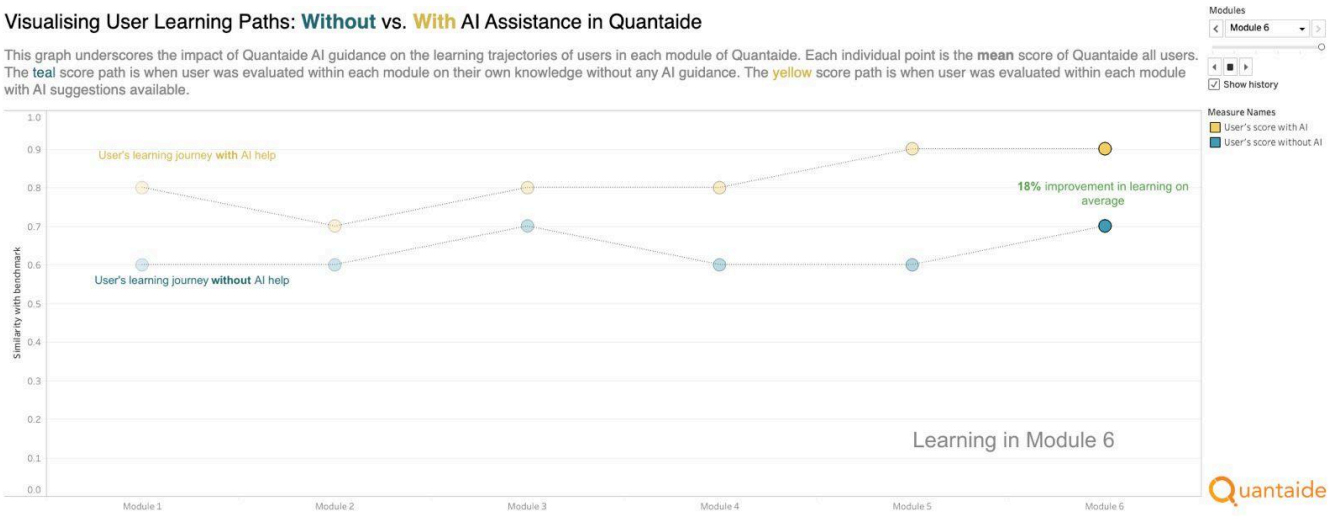
Evaluation Metrics Enhancement:
Augmenting existing evaluation metrics with additional parameters such as response time, click-through rate, and parsimony of users' responses will provide a more comprehensive assessment of Quantaide's effectiveness. Continued iteration and testing will refine the evaluation process to reflect evolving user needs and product features.

Expansion to Other Quantitative Research Areas:

Beyond surveys, Quantaide's vision extends to facilitating precise research across various quantitative methodologies, including experiments. By maintaining a focus on assisting users with limited background knowledge, Quantaide will continue to empower researchers in diverse domains to conduct tailored and impactful studies.

10. Appendix

Figure 1
Impact of Quantaide AI guidance on learning trajectories of users



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