



MateriALL

auto-generated classroom materials

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Summary

MateriALL is a Google Add-on that helps teachers generate and design classroom materials using their existing curriculum. With MateriALL, teachers take content from slide decks they have already created and generate different kinds of questions that, together, can make up worksheets, quizzes, etc. MateriALL's natural language processing capabilities suggest questions based on selected slide content, while its customization-first, hands-off-second approach to worksheet design results in personalized yet well-formatted materials for each teacher.

MateriALL was researched, ideated, designed, and built by four students from the University of California, Berkeley's School of Information as part of their final capstone project for the Master of Information Management & Systems program. MateriALL will be available for free installation on the Google Workspace Marketplace in May 2022.

Introduction

Existing research about learning tools often centers around student learning and development. As a result, the artifacts that come from these studies are very student-centered [1]. This leaves an integral real-world user out of consideration - the teachers.

Our research reveals that K-12th teachers do not have enough time for their jobs. Outside of classroom instruction, they often need to invest extra hours making materials for their lessons, even during the weekends. Teachers in their earlier careers especially spend a lot of time creating materials, as they do not have existing content from previous years to work off of or edit. Furthermore, the impact of the COVID-19 pandemic has added social-emotional stresses to both students and teachers alike, and educators must now juggle new, arguably more important priorities whilst still making their materials. In total, the process of making materials takes away from the time that teachers could be using to invest personally in students' growth. Thus, we propose that **by automating the material creation process, we can ease teachers' burdens of lesson planning and enable them to spend more time doing what they love and want - helping students grow.**

To support our proposal, we put forth MateriALL, a solution that takes teachers' existing materials (ie. slide decks) and automatically generates additional, customizable activities (ie. worksheets) for use in the classroom. MateriALL is the result of nine months of research, ideation, design, and development as part of our final capstone project for the University of California, Berkeley School of Information's Master of Information Management & Systems program. The MateriALL team, as well as the process we adopted, represents the interdisciplinary values of the School of Information: research, design, software engineering, and data science. This report is an in-depth documentation of the journey of MateriALL, from initial ideation to final deployment.

Background Research

For one of our class projects in Fall 2021, we had an opportunity to potentially collaborate with a technology-based embodied learning research team. We started this project by interviewing K-12th teachers about their perceptions of embodied learning. However, we found out that teachers have a lot to do, and having extra work to coordinate embodied learning would add more work to their plates [2]. Because of this, we pivoted from embodied learning to more general teacher-related topics around lesson planning and material creation. To kick off research for our final capstone project, we conducted open-ended, qualitative interviews with K-12th teachers (without the emphasis on embodied learning) in order to uncover what needs and pain points would emerge related to their work. In addition to our interviews, we also conducted an online survey to gather more quantitative data to complement our qualitative interviews.

From our research, we found that teachers want to prioritize investing personally in their students' growth, especially in light of the impacts of the COVID-19 pandemic. During the interviews, teachers mentioned that their schools were currently focusing on students' socio-emotional learning, and that they were teaching students how to be students in a classroom again. Teachers in Title I schools (schools in which children from low-income families make up at least 40 percent of enrollment [3]) especially reported difficulties in supporting their students' growth and development.

However, teachers have many secondary priorities, such as lesson planning and material creation, that limit their ability to fully invest in their students. According to our survey, new, young teachers especially need to spend a lot of time making worksheets (Figure 1).

Most Time-consuming Part of Preparing Lessons and Materials

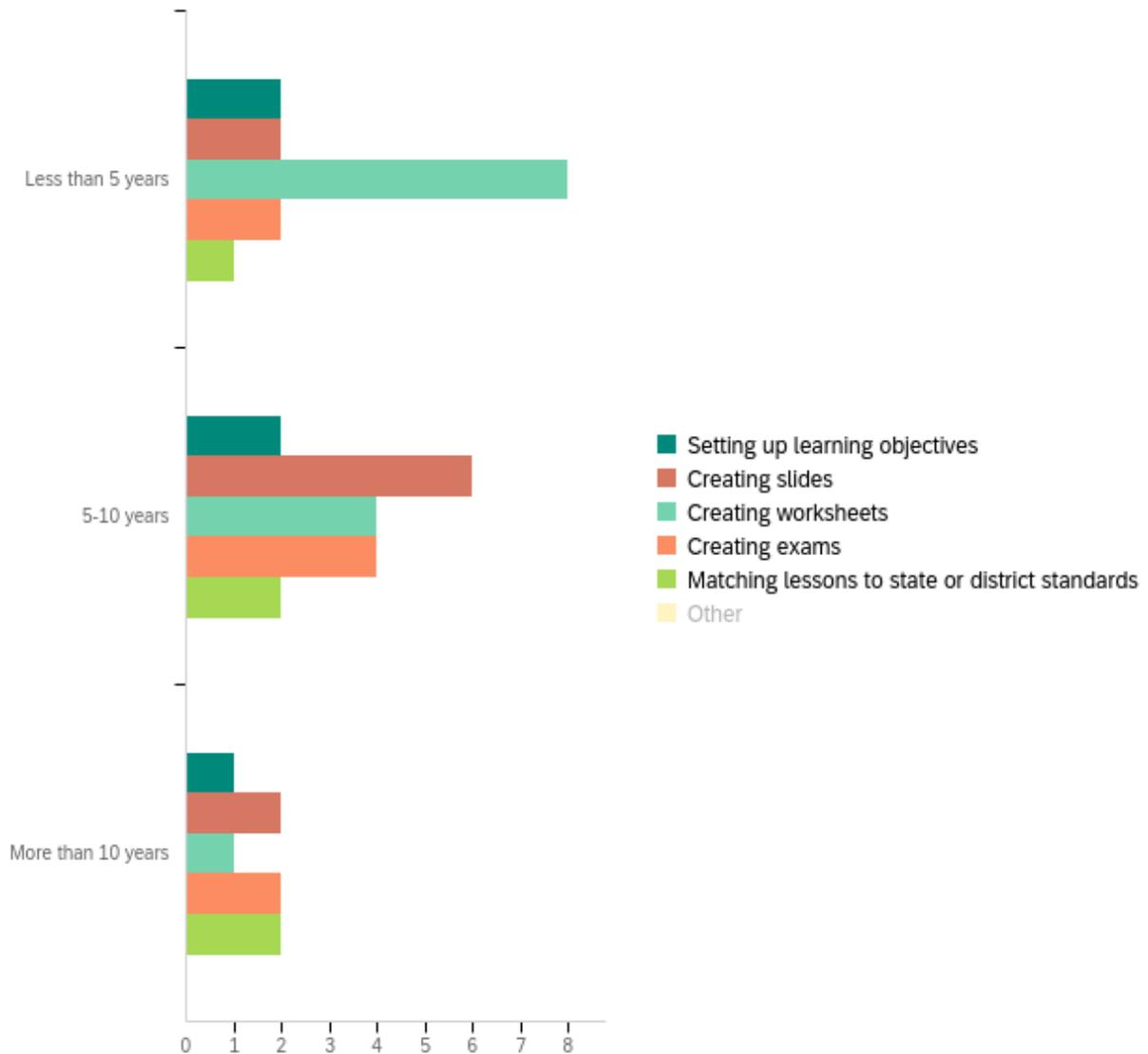


Figure 1: Survey result - most time-consuming part of preparing lessons and materials

From our follow-up interviews with teachers, we found that newer, less experienced teachers take a lot of time creating materials because they do not have pre-existing materials to edit.

This led us to the major question that would guide us for the rest of our project: **How might we make the lesson planning process more streamlined so that teachers have time for other responsibilities?**

Ideation

Our background research revealed the many pain points that K-12th teachers deal with during their jobs. In order to narrow down to the specific pain points we wanted to address, we considered major factors such as our own expertise (or, non-expertise in the education field), time, interests, and resources.

To further guide us in the ideation process, we considered what current tools teachers use in the lesson planning process. From our survey, we found that many teachers use Google Drive products to organize and design classroom materials (Figure 2). Specifically, many teachers create slide decks using Google Slides before making classroom materials such as worksheets and quizzes using Google Docs. These insights led us to consider how we might take advantage of existing functionalities in Google Drive to improve teachers' material creation and management process.

Digital Tools for Preparing Lessons and Materials

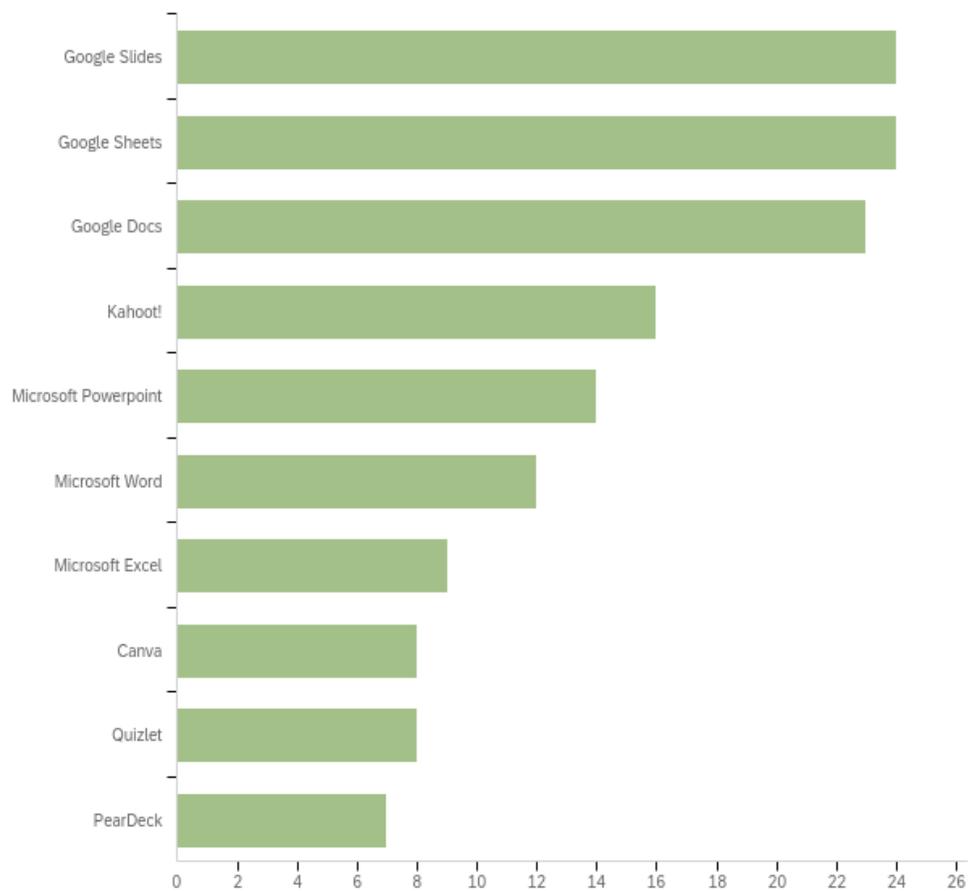


Figure 2: Survey result - Digital tools that teachers use to prepare lessons and materials

Altogether, these insights led us to consider a solution that would take teachers' existing materials (ie. slide decks) and transform them into additional materials (ie. worksheets). Taking into consideration our own expertise, we argue that by automating at least some part of the lesson planning process, we can give more time back to teachers, which they can then invest back into their top priority: taking care of their students. We also decided that making a Google Add-on would be the most user-friendly platform because it builds upon Google Drive tools that many teachers already use.

Adjacency Analyses

We supplemented our ideation process by conducting two analyses of existing products. The first one focused on existing digital solutions for worksheet generation and design. The following findings ended up being the most impactful for our project.

- Existing solutions for worksheet generators and creators assume that teachers already know what content will be their inputs but do not take advantage of the actual existence of this content. Many take a template-like approach where teachers must manually write their own content into input boxes (ie. TEFL.NET, Canva). **How might we use teachers' pre-existing content, and the way it is organized, to automatically generate materials?**
- Our research revealed that teachers make many careful decisions when designing their worksheets (ie. answer space, number of questions, etc.). However, existing solutions for worksheet generators do not provide design clarity until the end of the user journey, nor do they give teachers many customization affordances (ie. TEFL.NET, Canva, Math Goodies). **How might we design for transparency, personalization, and design flexibility in our solution?**

We also conducted an adjacency analysis over other Google Add-ons for the education sector. The following finding ended up being most impactful for our project.

- Google Add-ons use sidebars when there is content being dynamically manipulated in context of the document, slide, etc. that it exists in (ie. Pear Deck, Scratch Blocks). On the other hand, they use modals when the interactions require more finesse and/or when contextual content manipulation is less important (ie. MathType).
- Google Add-ons are powerful when they can make use of the entire Google Drive ecosystem (ie. Automagical Forms). Because a teacher could ostensibly use Google Slides, Docs, and more to plan their lessons, employing the Google Add-ons' ability to move between these applications mimics the workflow a teacher might employ when moving through their Google Drive.

Design and Testing

Following ideation, our group worked on design, testing, and development in parallel to maximize our project timeline. Design work was heavier in the first half of the project, while development was heavier in the latter half. Testing occurred throughout. This section documents MateriALL’s design and user testing process.

We went through multiple iterations of low, mid, and high fidelity screens and prototypes in the design of MateriALL. Major iterations were interspersed with concept and usability testing, which then informed design decisions for the following iterations. Major phases of the design process, design decisions, and testing results are documented in this section.

User Flow Planning

We started by planning the user flow of MateriALL, to understand (a) what steps a user would need to take in order to make a worksheet with MateriALL, (b) where these steps would exist within the MateriALL information architecture, and (c) how much automation MateriALL should be responsible for. This user flow (Figure 3) was informed by our background research and analyses of existing products, to make sure we were optimizing for both teacher needs and pre-existing experiences with other educational products.

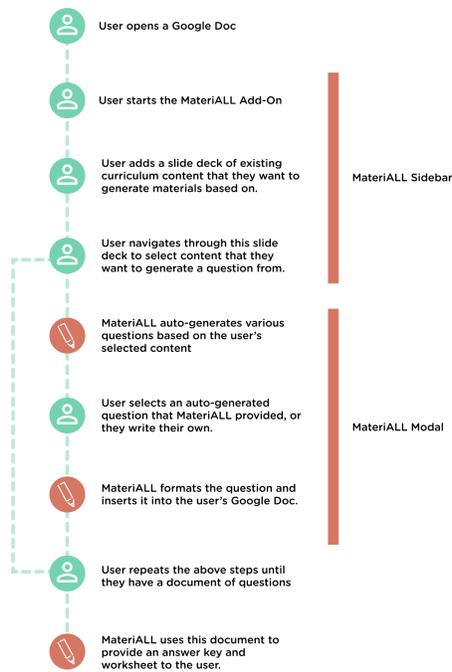


Figure 3: MateriALL’s step-by-step user flow

Mid-Fidelity Designs

We began with initial hand sketches, then mid-fidelity screens (Figure 4) designed with Figma for our design process. During this stage of the design process, we focused more on fine-tuning our overall flow and concept rather than specific user interactions and details.

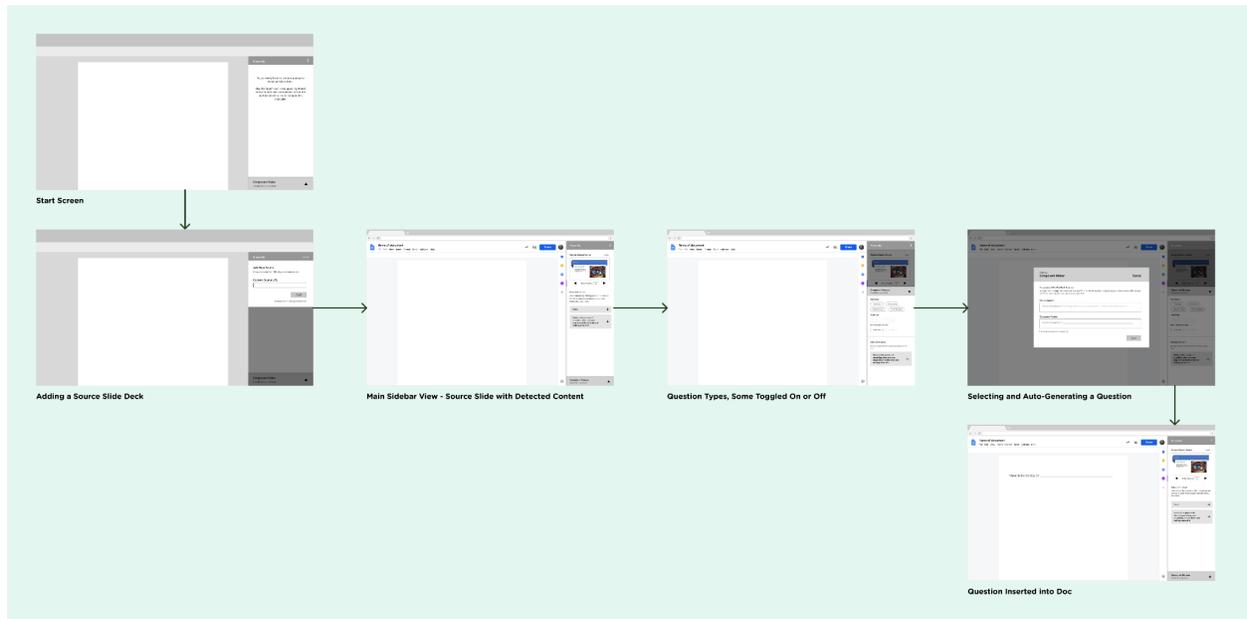


Figure 4: Mid fidelity 1.3 screens

Our mid-fidelity screens demonstrated a simple, error-free user flow from start to finish. As seen in Figure 4, the user in our mid-fidelity screens would start with no source content. They would enter the URL of their source slides, look at what detected content MateriALL could find from their source slides, and select from this detected content what they would like to generate questions from. Next, the user would be able to see what questions they could generate, represented by enabled or unenabled selections. From here, the user would select what question to generate, move to a pop-up modal to take a look at the generated question, then insert it into their document.

Concept Testing

We used our mid-fidelity screens (Figure 4) to conduct concept testing with K-12th teachers in the United States. We showed teachers these mid-fidelity screens, which did not include interactions, and got feedback and opinions about the concept of MateriALL.

Teachers liked that MateriALL is a Google Add-on. They could create materials based on their own slide decks and use multiple devices (their school computers and their personal computers) to edit these materials. A Google Add-on being private to their own account was

another reported advantage. In addition to the worksheets that we originally thought about, one teacher suggested that MateriALL would be useful to create guided notes. Her current guided notes do not match with the slides that she creates, and students get confused during the note-taking process.

Teachers mentioned that our design is simple and intuitive and emphasized that we should keep it that way since “teachers are scared of lots of buttons.” Also, even though they liked the automatic material creation concept, they wanted both automation and customization: “If it auto-generates for me, I have a starting point.”

High Fidelity Designs

Our concept testing results confirmed the value of MateriALL and its user flow. With this, we moved into the high fidelity design phase, making edits and also adding more defined functionalities and interactions. This section will cover some of the major design decisions we made during this period. For a complete overview of all of MateriALL’s affordances, see the “Final Product Overview” section.

One major design decision made during this time was MateriALL’s overall visual style. Instead of using a pre-existing design system, we decided to create one for MateriALL to stylistically set it apart from other Google Add-ons (Figure 5). Visual and color accessibility were taken into consideration during this time.

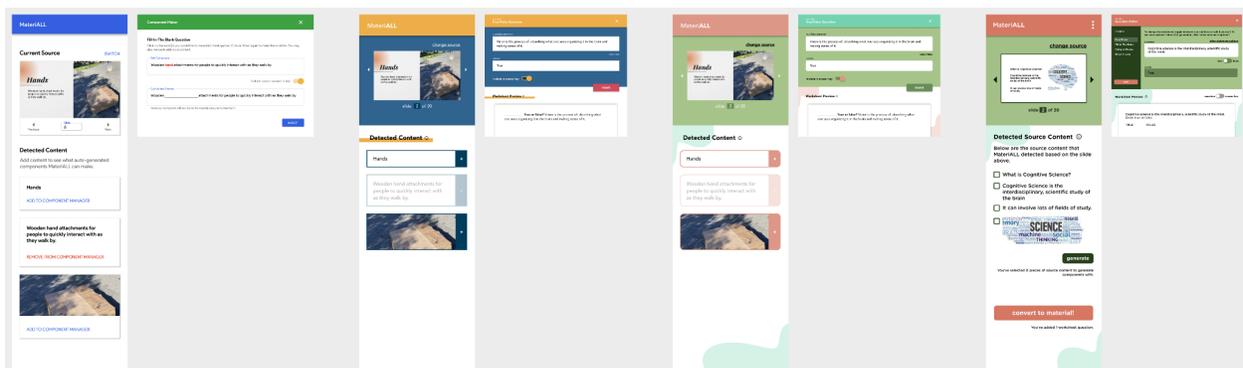


Figure 5: From left to right, the evolution of MateriALL’s visual style

We ultimately decided on a color palette that we informally called “pale watermelon.” The playful “pale watermelon” palette conveys a sense of lightheartedness that mirrors MateriALL’s overall goals for a lightweight, hands-off user solution. With this, we created design components for MateriALL, which helped us accomplish faster, more cohesive iterations. MateriALL’s design system documentation can be found in the appendix.

In our mid-fidelity phase (Figure 4), we assumed that only certain question types could be enabled for certain content. However, we found through concept testing that users expected

more flexibility. In our high fidelity phase, we, therefore, decided to allow users to create any and all types of questions with any and all combinations of content (Figure 6).

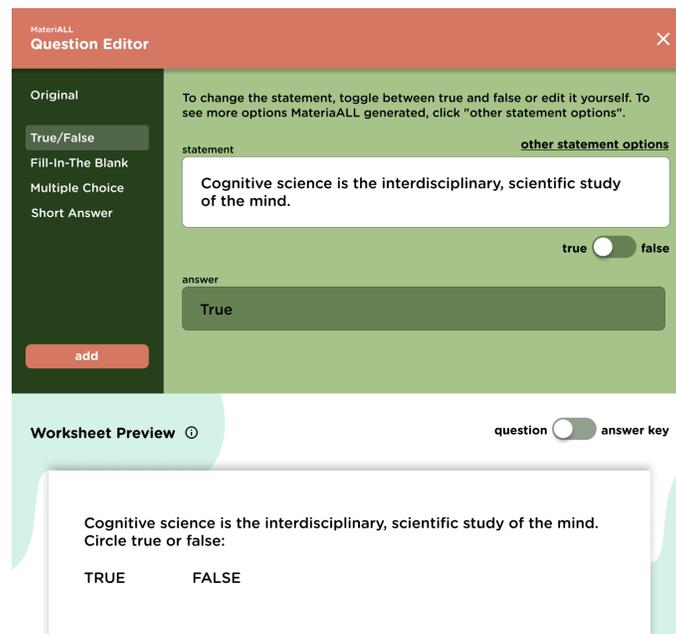


Figure 6: The Question Editor modal, where users can generate all types of questions through the options in the sidebar

With the technical functionalities defined, we also were able to design interactions for all the question types we wanted to support as well as their own affordances (Figure 7).

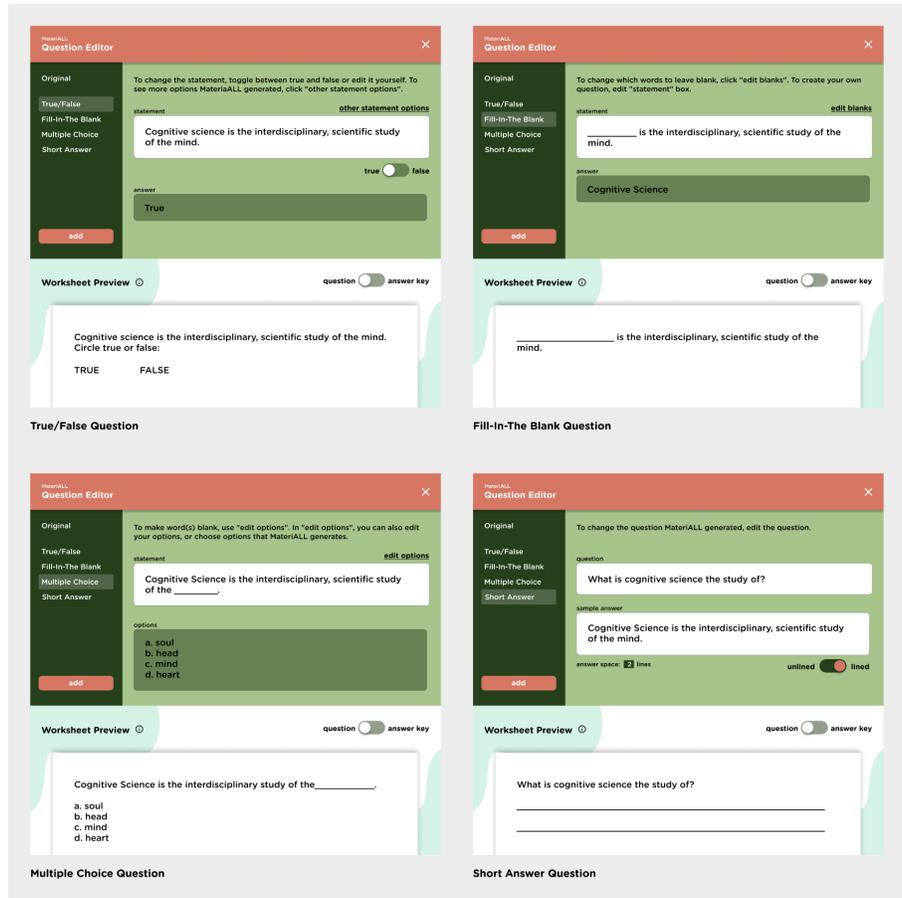


Figure 7: Options for all of MateriALL's supported question types

Finally, we defined the user flow for adding questions to a user's Google Doc (Figure 8). Considering both user needs for flexible editing as well as technical limitations on Google Add-ons, we decided that MateriALL would first import questions into the user's Google Doc as an answer key. This way, users could make additional edits and add more questions, without having to jump between two Google Doc screens. Once a user is finished, they can use MateriALL to convert their answer key into a worksheet.

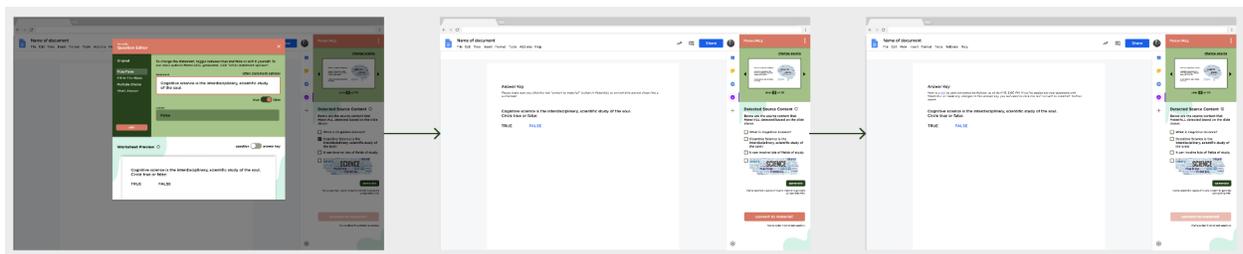


Figure 8: The user flow of adding a question to their answer sheet, then converting the entire answer sheet into a Google Doc. We use Google Doc copywriting to explain this process and remind them to convert!

Usability Testing

We used the high fidelity screens documented in the above section to conduct usability tests with K-12th teachers in the United States. We let the teachers explore our high fidelity screens and interactions, and got feedback and opinions about the MateriALL interface.

One of the main themes that came out of the usability test related to consistent use of color and expected interactions. White text boxes are expected to be editable, while dark green boxes are not expected to be editable by users. The biggest confusion came when the expected interaction was not happening. The conversion from the MateriALL interface to the worksheet in Google Docs was expected to be done when the pop-up screen was closed. As the “convert to material” button was far down on the bottom, the participants could not find the button easily. Also, when the material was converted, they expected to see the worksheet, not the answer key.

In creating the multiple-choice questions, the interface was easily understood. Clicking checkboxes to include the answer choices to the question was intuitive. Also in this interface, the participants liked having an option to choose the number of blanks in the question.

There were a few important factors that the participants pointed out. The participants liked how MateriALL can automate the process, but they also wanted to have an option to customize their questions. They thought that MateriALL can be a great tool to create guided notes for the students, so that students can go through the lesson and work on the worksheet in front of them. The participants also suggested that for short answer questions, they would want to include sample answers or rubrics in the answer key, so that they can grade more easily.

We used the findings from our usability tests to inform some final design decisions, which are reflected in the “Final Product Overview” section.

Back-End Development

Natural Language Processing

To support auto-generated suggestions for users, we implemented NLP (natural language processing) functions. We explored four approaches for the four question types that MateriALL supports. Due to computing constraints, we are unable to support NLP functionality for auto-generated short answer questions. As a result, we focused on building three primary NLP functionalities: creating false statements (for true/false questions), identifying important phrases in a sentence (for fill-in-the blank questions), and generating multiple-choice options. We had hoped to include more advanced capabilities, but due to computing and resource constraints, we did not have the budget to use more computing-intensive models. Because of this, we focused our efforts on meeting our three key goals, while being mindful of our constraints.

False Statements

To create false statements for true/false questions, we found this task to be quite challenging after some investigation. Because language is complex, there is a lot of complexity in changing a statement from true to false. Since there were no existing libraries to do this, we wanted to focus our efforts on using something existing that could be helpful for users. We came up with the idea of using antonyms, since this was feasible and could serve the purpose of creating false statements in some cases. This was built using a model from Wordnet from NLTK [4]. Using this model, we could replace a word in the sentence with its antonym, and it would create a false statement.

- Example Input: “The Pacific Ocean is **west** of the United States”
- Example Output: “The Pacific Ocean is **east** of the United States”

Generating Sentence Blanks

To identify important phrases in a sentence in a feasible way, we focused on identifying noun chunks. We used the spaCy library [5] with a trained pipeline for English based on text from the web. We used the smallest mode, (“en_core_web_sm”) due to computing constraints. With this model, we can use the library to get the noun chunks of a sentence. For our use case, we want to use these noun chunks to suggest one blank for the user, so by default, we will blank out the longest noun chunk.

- Example Input: “George Washington was the first US president”
- Example Output: “George Washington was _____”

Multiple-Choice Options

To generate multiple-choice options, we used the Gensim library [6], using a pre-trained model from NLTK (Natural Language Toolkit) [4]. This model includes the approximately 44,000 most common words pruned from a model trained on the Google News Dataset (consisting of 100 billion words). Using the model, we can use the library functions to find the

most similar words to a given word. In our case, we used this to generate multiple-choice options.

- Example Input: “oxygen”
- Example Output: [“nitrogen”, “carbon”]

NLP Limitations

As mentioned in the intro of this section, generating short answer questions was constrained by computing power. We were able to implement this feature on our own machines, but hosting it on a web server was outside our budget due to high memory needs of the model. Although we can't include this feature in our final deliverable, we would still like to share our approach. We built this model adapted from an open-source library found on GitHub “question_generation” by user @patil-suraj [7]. We used the provided model from the library, which utilizes transformers to generate questions based on a text passage. In our case, we could use this to generate questions based on content from a slide.

- Example Input: “Cognitive science is the interdisciplinary, scientific study of the mind”
- Example Output: “What is cognitive science the study of?”

In addition to computing limitations, there are more general limitations that apply to all the other models we used. These models may sometimes provide nonsensical suggestions, especially because of words with multiple meanings or other language complexities. Although the suggestions generated by any of the above models will not be perfect (as with any NLP model), we think providing this guidance will be helpful to users. Users will still have the option to customize any of the text themselves. These are meant to serve simply as suggestions and not intended to be mandatory requirements.

Back-End API

For the front-end to access our natural language processing features, we created a back-end API (application programming interface). The front-end can pass in different parameters to the API like a sentence, and the API will return the auto-generated suggestions. This API was built using Python Flask, and is hosted on Heroku. Based on the design of the user flow, we created one primary endpoint that encompasses all three NLP functionalities rather than creating separate endpoints. This will reduce latency because the front-end only needs to call the API once, and reduce any wait time for the user.

Front-End Development

Google App Script

As most of the teachers use Google Slides and Google Docs to create their teaching materials nowadays, our application is a Google Add-on based on Google Docs to make it painless for teachers to use. Consequently, teachers who are already experienced with Google Drive tools will have an easier time also using MateriALL.

The MateriALL Add-on is created with JavaScript, HTML, and CSS on Google Apps Script, “a cloud-based JavaScript platform that lets you integrate with and automate tasks across Google products” [8]. In addition, we used the Google Slides API [9] to get the content from teachers’ slides, and we interacted with our back-end API to provide suggestions to questions and answers for teachers. Furthermore, we used some methods provided by Google for Google Docs Add-ons to insert, extract, and create new documents for answer sheets and worksheets [10].

Link to GitHub repository: <https://github.com/CYJOYC/MateriALL>

Final Product Overview

MateriALL Product Principles

Theme	Research Insight	MateriALL Product Principle
Target Users	<p>We uncovered that newer teachers with less experience, particularly those teaching in Title I schools, have a unique set of needs. These teachers would like to spend more time to meet their students' social and emotional needs, and teaching pedagogy is not as high of a priority, especially in the online to in-person transition phase. But because newer teachers do not have a repository of prior materials to reuse in the classroom, these teachers often dedicate extra hours outside the classroom creating these materials instead of focusing on their other priorities.</p>	<p>MateriALL's primary use case is to support these newer teachers. MateriALL helps teachers reduce their time spent on creating worksheets, which is taking up a lot of their time. This is so that teachers can reallocate their time to tasks that can't necessarily be automated, like more time interacting with their students.</p>
Automation	<p>According to our survey results, teachers reported spending the most time creating worksheets. From our interviews, this was reported to be a tedious process with lots of manual, repeated work.</p>	<p>MateriALL focuses on automating the most time-intensive part of teachers' workflows, which is taking existing slide decks and converting them into worksheets. This is because many teachers had existing slides and spent the most time creating new worksheets.</p>
Suggestions	<p>Many teachers were drawn to tools that provided them with both easy and satisfactory guidance. For example, several teachers mentioned liking Canva because it easily provided them visually appealing suggestions for their</p>	<p>MateriALL provides users with quick and easy auto-generated suggestions. These suggestions can help users with both the formatting (through different question types) and the content itself (through auto-generated</p>

	needs.	question wording and answer options).
Customization	Although teachers can use existing materials such as those provided by other teachers or the Internet, most teachers reported needing to personalize these materials to suit their own students and teaching styles.	MateriALL allows users to edit or remove any auto-generated suggestions. Users are able to add any of their own content.
Adaptability	Teachers don't have the time to learn new tools and often choose tools that are easy to integrate with existing practices.	MateriALL is designed as a Google Docs Add-on. This can be easily downloaded and incorporated into Google Docs, which is a common tool used amongst teachers.
Intuitive	From usability testing, users were able to quickly learn how to use the tool without much guidance.	MateriALL follows design best practices, so that it is an easy-to-use tool that can quickly be learned.

Installation and Set-up

Users can install MateriALL directly to their Google Drive account via the Google Workspace Marketplace. For initial installation, they can click the "Add-ons" option in the Google Doc taskbar, select "Get add-ons," and search for MateriALL in the following pop-up. After finding MateriALL, users can click "install" to begin the installation process for MateriALL. After initial installation, MateriALL will always be available from this user's Google Drive account.

Once MateriALL has been installed, users may open MateriALL in any of their Google Docs at any time. MateriALL will start out appearing as a sidebar in the user's Google Doc (Figure 9). MateriALL starts out in sidebar form because this view allows users to dynamically view both their Google Doc and the MateriALL interface at the same time.

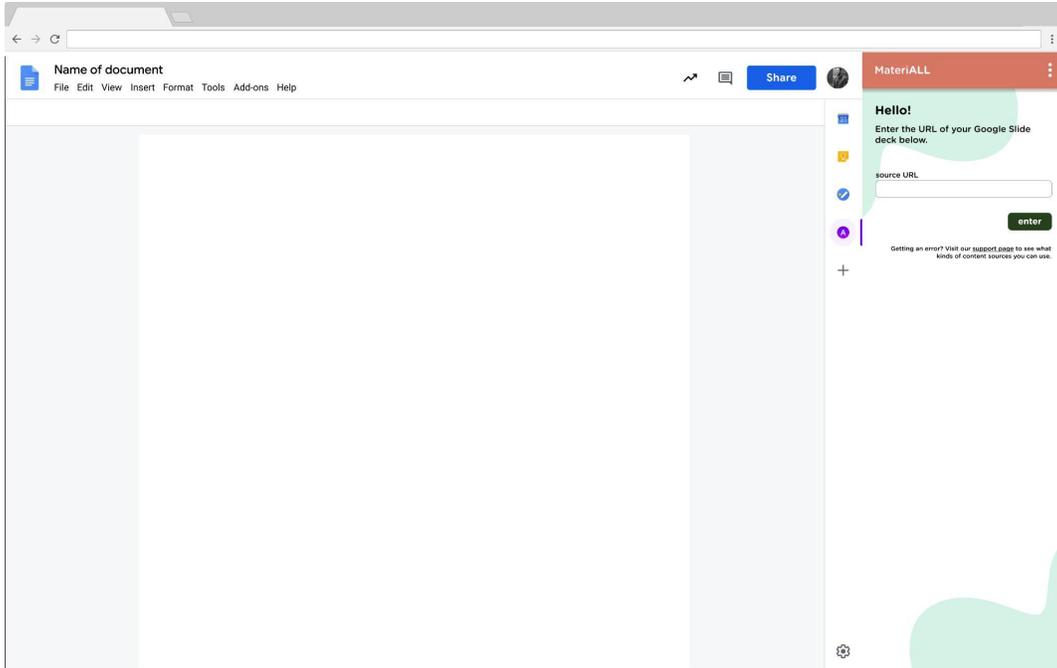


Figure 9: MateriALL, as it appears from start as a sidebar on a Google Doc

Upon start, users will be prompted to copy and paste a source URL into an input box to load their existing slide deck that they wish to generate materials from (Figure 9). On the back end, MateriALL takes this URL and identifies the corresponding presentation ID, which is a feature of the Google Slides API [9]. If a user has mistakenly connected the wrong slide deck, or if they wish to generate questions from a different one, they can change their source URL on the next screen (Figure 10).

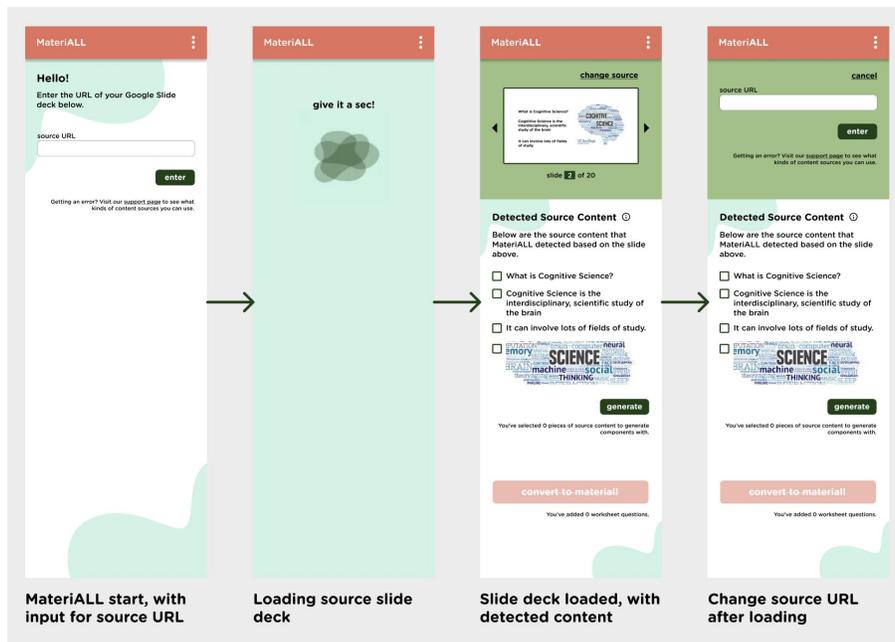


Figure 10: User flow of connecting and changing a source URL

Selecting Content

Once a source slide deck has been loaded into MateriALL, users may freely toggle between slides within this slide deck. For each slide, MateriALL uses the Google Slides API [9] to detect the content on that slide (ie. text, images). These appear to users as a list of content with checkboxes (Figure 11). Users can select as many pieces of content as they wish to generate questions with, using these checkboxes. After selecting content, users can click the green “generate” button to start generating and editing the content into questions.

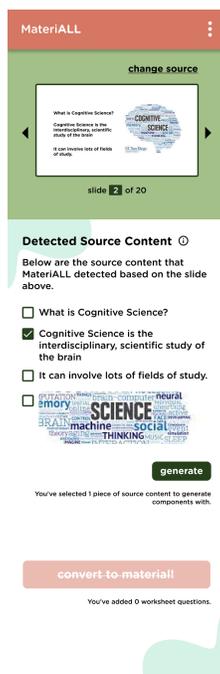


Figure 11: Detected source content displayed for a particular slide – in this case, the user has selected one piece of content.

Generating and Editing Questions

After clicking the green “generate” button, a modal will appear on the user’s screen (Figure 12). This is the Question Editor, where users can generate questions with MateriALL’s NLP technologies or edit question content themselves. These functionalities exist in a modal, rather than a sidebar, because they require more fine-tuned interactions and do not necessarily require users to be aware of what is also on their Google Doc. On the back end, MateriALL uses its back-end API to generate options for all question types, which helps reduce loading time while users work within the Question Editor.

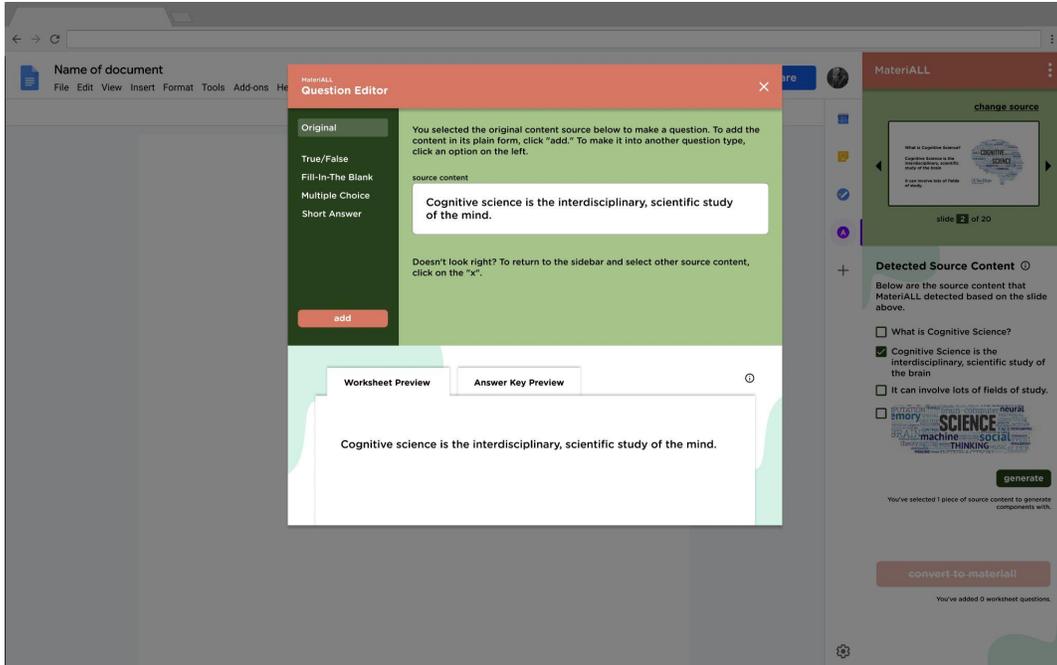


Figure 12: The Question Editor modal, as it first appears on user's screens.

The Question Editor modal has a sidebar with options for different types of content that MateriALL can generate and/or format. These are covered in detail in the following sections. Additionally, the Question Editor modal will always have a red “add” button for users to add their content to their Google Doc, and two tabs at the bottom of the modal that allow users to preview their content as either a worksheet question or as an answer key.

Original Content

Upon starting the Question Editor modal, users will always begin on the “Original” option, which allows users to add content to their Google Doc as it is, without any additional formatting (Figure 13). For users who want to generate more complicated questions, this view is helpful because it enables them to review content that might have been concatenated together from multiple detected content selections in the sidebar, or non-text content such as images. For users who want to insert the content in its original form, this affordance is also helpful because it ensures version control between their Google slide deck and their Google Doc.

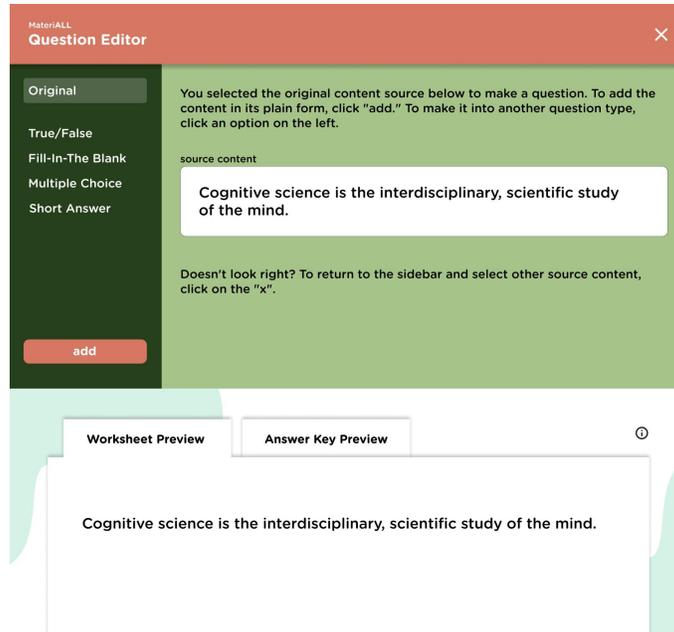


Figure 13: The “Original” option in the Question Editor, which allows users to insert content directly into their document

True/False Questions

Users can also elect to create true/false questions out of their selected content. Upon navigating to the “True/False” option in the Question Editor sidebar, users will see their selected content, with the default option as “true” (Figure 14).

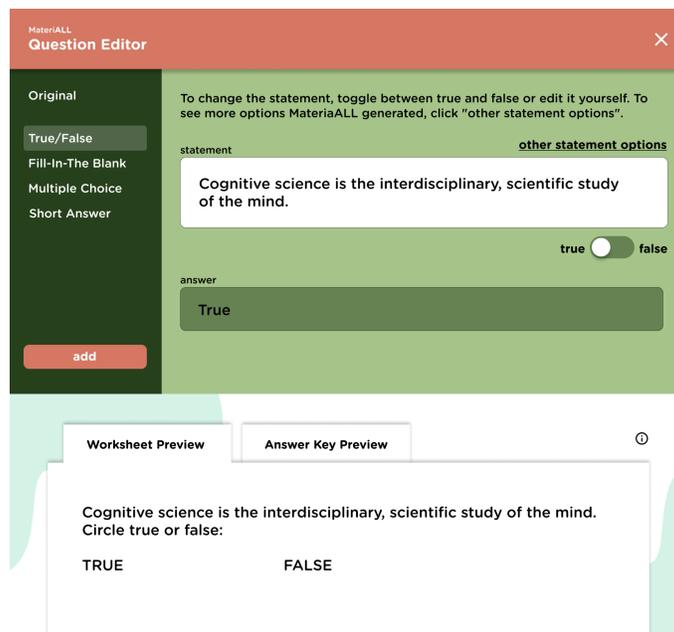


Figure 14: The starting point of generating a true/false question, where the content is true

Users can use the true/false toggle to quickly switch to a false statement (Figure 15). When users toggle to false, the statement switches to a false statement that was generated by the MateriALL API, based on the original content.

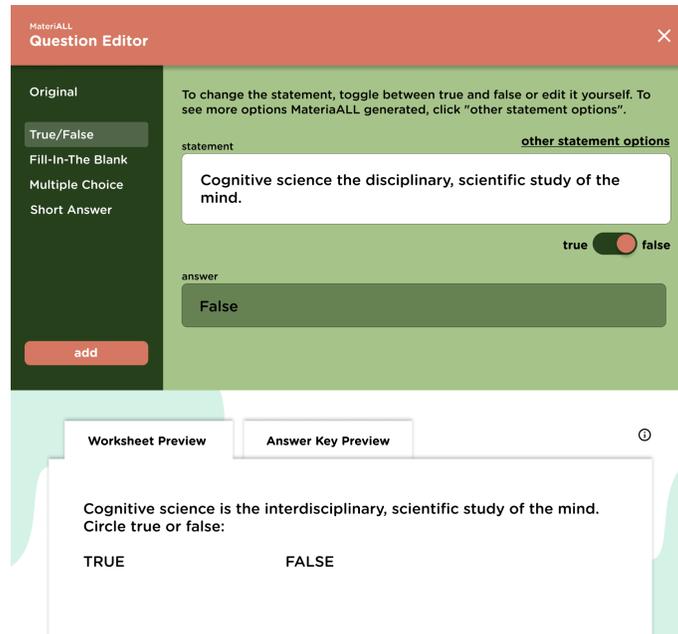


Figure 15: The statement, now made false upon the user's toggle switch and MateriALL's back-end API

However, users may not be satisfied with MateriALL's auto-generated false statement. In this case, they can click the "other statement options" link to select another one of MateriALL's auto-generated statements (Figure 16).

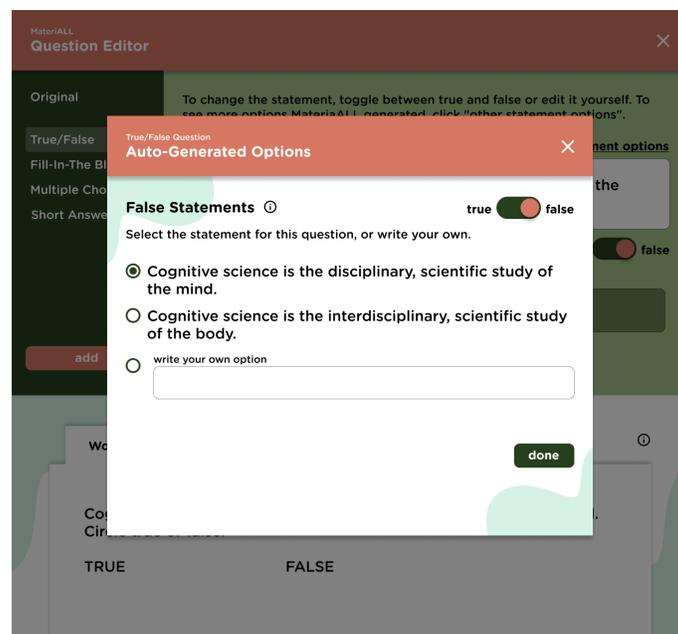


Figure 16: More auto-generated false statements for users to choose from.

If a user is further unhappy with all of the auto-generated options, they can edit the statement themselves manually. There is functionality to do this both within the auto-generated options submodal or within the Question Editor modal itself via the input boxes. Because MateriALL's Question Editor calls the MateriALL back-end API upon start, the auto-generated options that MateriALL provides do not update with a user's manual edits. This is made clear to the user, though, with a red border to indicate that a manual edit was made (Figure 17).

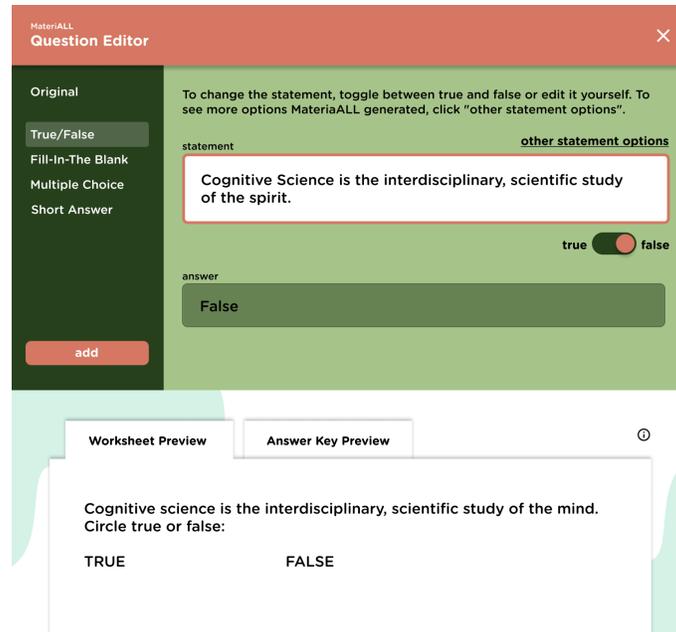


Figure 17: The false statement manually edited by the user, as indicated by the input form's red border.

Fill-In-The Blank Questions

Users can create fill-in-the blank questions from their selected content by clicking the "Fill-In-The Blank" option on the sidebar. Upon clicking this selection, users will see their original content, with a word or phrase replaced by MateriALL's fill-in-the blank API (Figure 18). MateriALL automatically chooses a noun chunk to make blank and, therefore, the answer to the question.

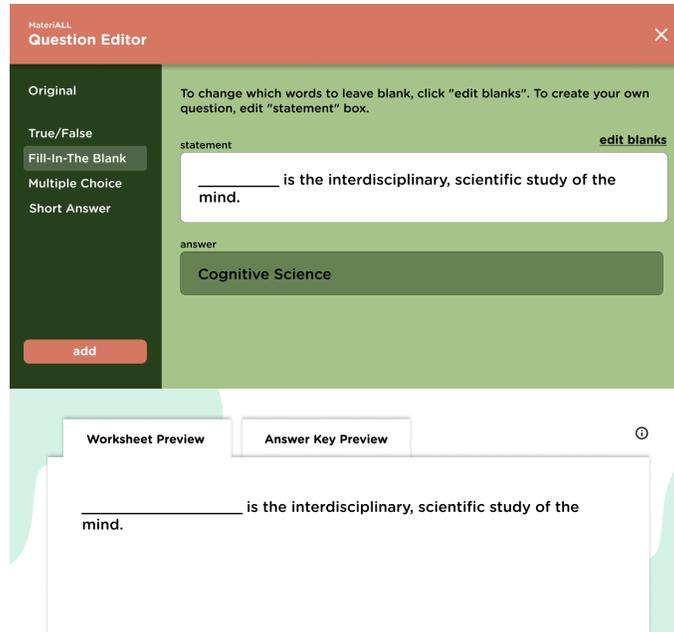


Figure 18: MateriALL's auto-generated fill-in-the blank statement. MateriALL will always choose the largest "noun chunk" to make blank for these questions.

There may be cases where users would like to make another, or more than one, word blank. In these cases, users can click "edit blanks" to open a submodal (Figure 19). In this submodal, users can click on individual words to toggle them blank or non-blank.

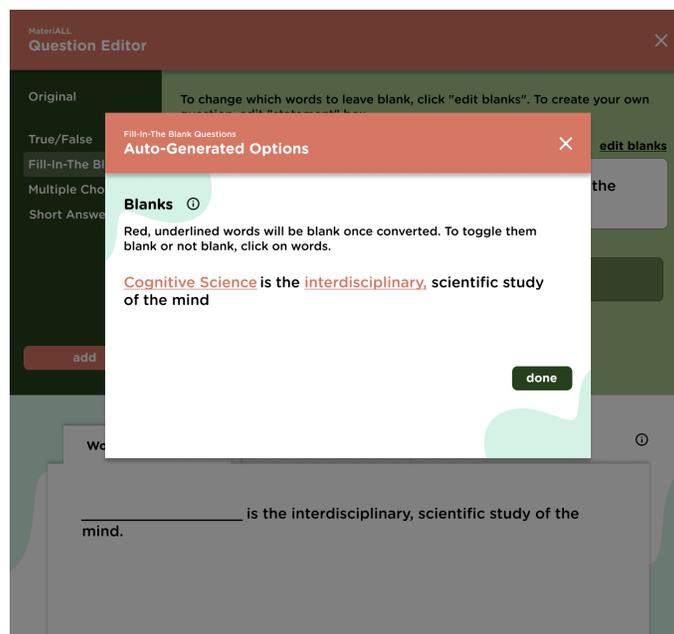


Figure 19: Users can click individual words in the fill-in-the blank submodal to make them blank or non-blank. Words that will show up as blank will be red and underlined in this view.

Similar to other options, users can further edit the statement manually via the appropriate input forms. A red border will appear around these forms, to inform the user that this content has been manually edited.

Multiple Choice Questions

Users can also create multiple choice questions with MateriALL by selecting the “Multiple Choice” option in the Question Editor’s sidebar (Figure 20).

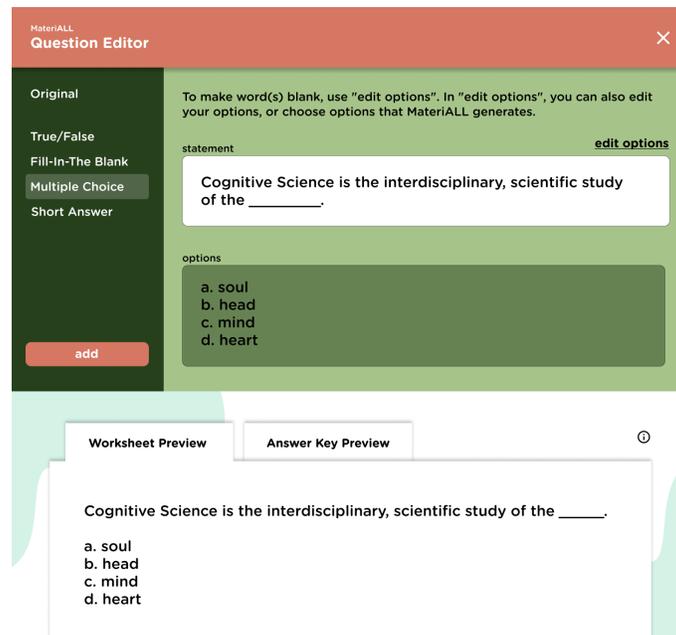


Figure 20: Question Editor, set to multiple choice

Users will need to perform an additional step, though, by selecting the word that MateriALL’s multiple choice API should target and show alternate options for. To do this, users click on “edit options” and use the submodal to select which word MateriALL’s API should target. Upon clicking on a word, MateriALL’s interface will show a list of other words its NLP model generated that could be used as potential multiple choice options. Users can select which words they want to use, or write their own (Figure 21). The original word will always appear as the correct option, and the user cannot un-check it.

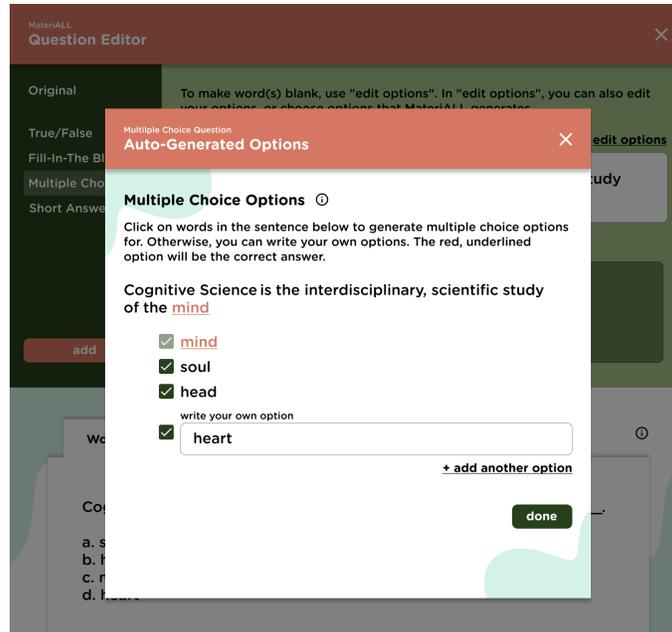


Figure 21: In this multiple choice submodal, the user has selected “mind,” to which MaterALL generated the additional options “soul” and “head.” The user also wrote in their own option “heart.”

Similar to other options, users can further edit the statement manually via the appropriate input forms. A red border will appear around these forms, to inform the user that this content has been manually edited.

Short Answer Questions

Finally, users can create short answer questions with MaterALL by selecting the “Short Answer” option in the sidebar. MaterALL currently does not support auto-generated short answer questions due to resource constraints (see “NLP Limitations”). However, user interviews informed us that teachers experience the most burden with formatting their short answer questions, as opposed to coming up with them. MaterALL addresses this pain point by providing an input for users to decide how much answer space to give to their students. Users can also toggle between lined and unlined answer spaces (Figure 22).

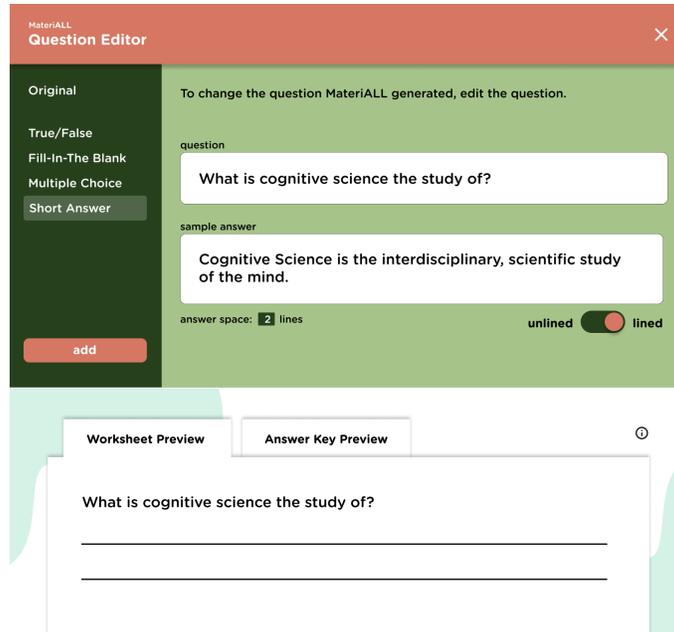


Figure 22: For this short answer question, the user has toggled settings to create a lined answer space of two lines.

Converting to a Worksheet

After a user is satisfied with whatever question they have generated and edited with MateriALL, they can click the red “add” button on the Question Editor sidebar to formally add the question to their Google Doc. Upon clicking this button, MateriALL will write the question to the user’s Google Doc using the Google Docs API [B]. The MateriALL Question Editor modal will disappear, so that users’ next interactions will take place in the sidebar.

In this first document, MateriALL will format the question in a way that looks more like an answer key than a worksheet (Figure 23). This is because users might want to add their own formatting outside of MateriALL, directly within their Google Doc. This also allows users to add many questions and make many edits, one after the other.

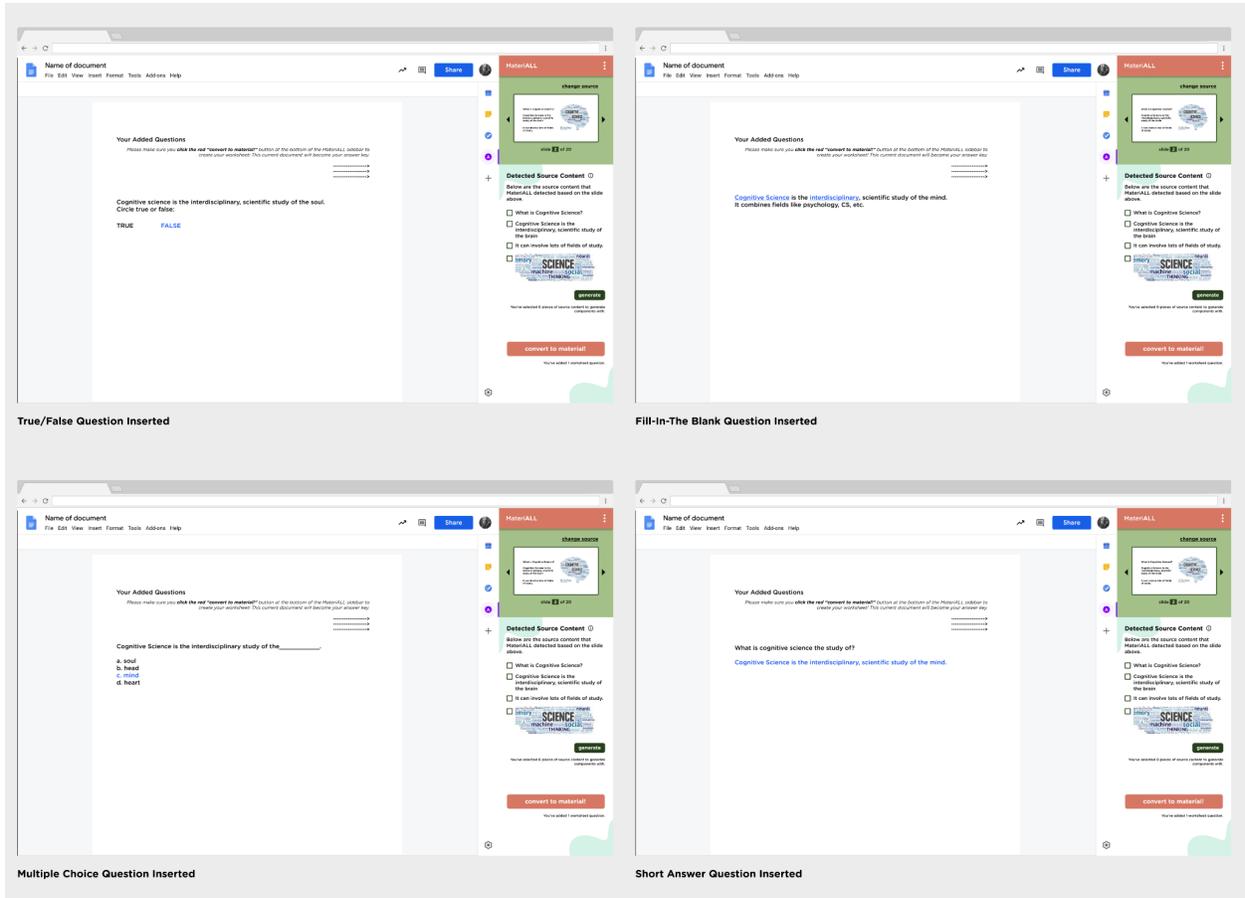


Figure 23: Examples of all the different question types that MateriALL supports, written into the Google Doc and ready for conversion.

Once the user has finished adding questions and making any additional Google Doc formatting choices, they click the red “convert to material!” button on the MateriALL sidebar. Users are reminded to do this with the copy that MateriALL inserted into their current Google Doc. Upon clicking this button, MateriALL will read the inserted questions on the current Google Doc and generate a new Google Doc in worksheet format so that the answers are not visible. This new worksheet Google Doc will be in the same Drive folder as the original Google Doc, and MateriALL will include a link to this worksheet Google Doc in the original Google Doc. MateriALL will also transform the original, current Google Doc into an answer sheet.

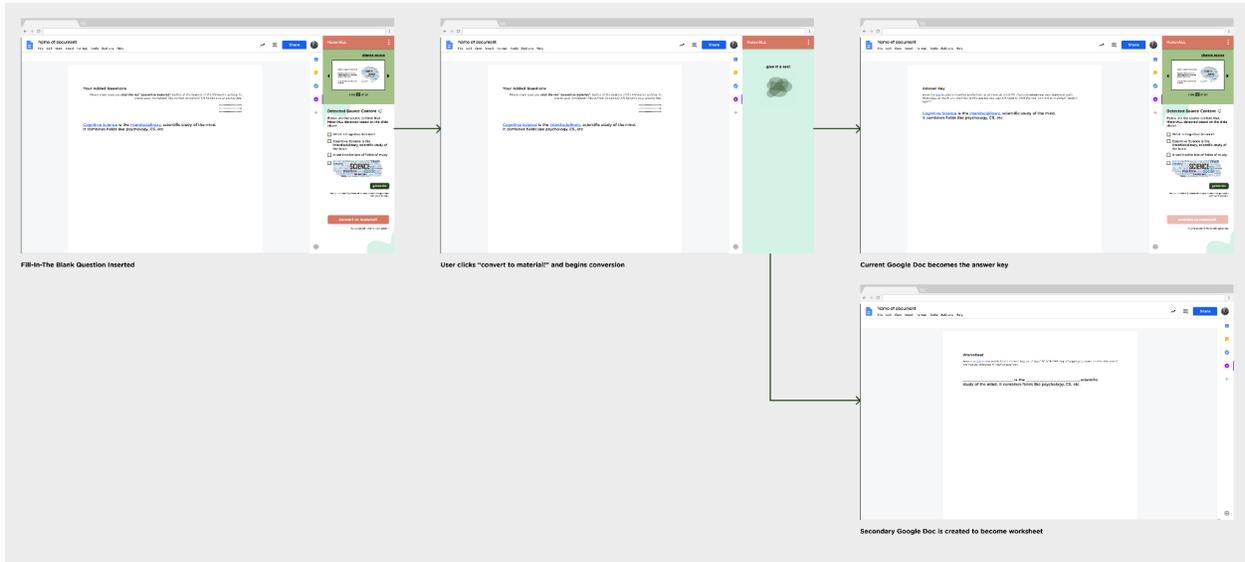


Figure 24: The user flow of adding a question, converting it, and seeing now both the answer sheet in the original Google Doc and the new worksheet Google Doc.

MateriALL accomplishes this process by targeting the relevant formatting on the original document and using it to determine what to leave blank, how to insert formatting, etc. MateriALL then uses the Google Docs API [10] to rewrite the current document as well as create a new document, which is the worksheet.

Impact and Future Work

Potential Impact

MateriALL has the potential to significantly reduce the amount of time teachers spend on creating their materials. Based on our survey data, teachers reported spending the most time creating worksheets. And from our interviews, we learned that teachers found this process to be tedious, manual, and not very enjoyable. Altogether, this means that MateriALL can have a major impact by both freeing up teachers' time and increasing teacher satisfaction. Because MateriALL helps teachers, we believe that this will ultimately benefit students as well. Teachers will be able to spend more time actually meeting their students' needs rather than tedious tasks like formatting a worksheet.

MateriALL Product Extensions

Based on the user research we've conducted, product extensions could further meet the needs of teachers. Due to time constraints, we could not implement these extensions into code, but we were able to visualize them as design mockups. We designed three potential extensions that can further reduce teacher workloads and time spent on the material creation process. These designs are a work in progress and will most likely be iterated upon in the future.

Subject-Specific

Our final deliverable aimed at meeting the needs of the general use case of a slide-based lecture with a corresponding worksheet. There were a few types of teachers whose use cases were different from our final deliverables'. For example, some math teachers do not use slides and may instead use a whiteboard or follow a textbook. The creation of math worksheets would also benefit from including functions to make it easier to draw mathematical figures (like geometric shapes) and write math-specific syntax. Beyond math, we can foresee how specialized features for other subjects like foreign languages, science, etc. could be helpful for MateriALL users. Therefore, we mocked up how MateriALL might work for a teacher who needs to make worksheets with multiple types of the same, technical question. In this case, we specifically addressed the use case of a teacher making questions for a geometry worksheet (Figure 25).

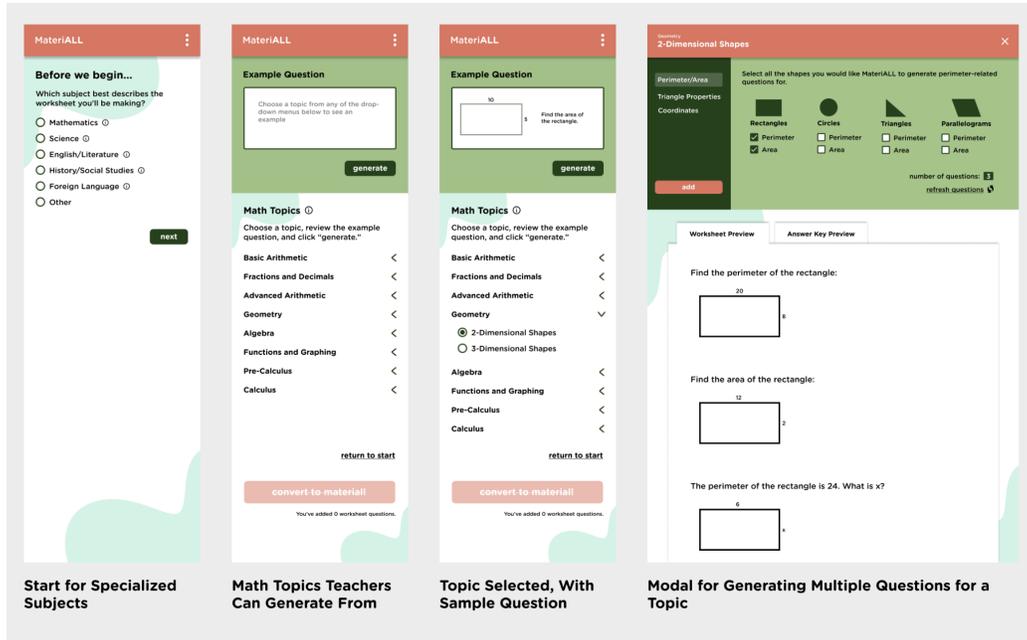


Figure 25: Potential screens for a teacher who wants to make specialized worksheets for math class – in this case, geometry.

Templates

Another feature that could significantly reduce teachers' time spent on making worksheets is to be able to reuse existing MateriALL templates. These could either be their own templates, or even templates that have been shared by other teachers. This way teachers do not have to start from scratch, and can simply connect a source (a slide deck) to a template, and it will auto-generate a worksheet based on the template and source. They would only need to spend time making any edits to the template and auto-generated content, rather than starting from an empty document. Therefore, we mocked up how MateriALL might support creation of and reuse of worksheet templates (Figure 26).

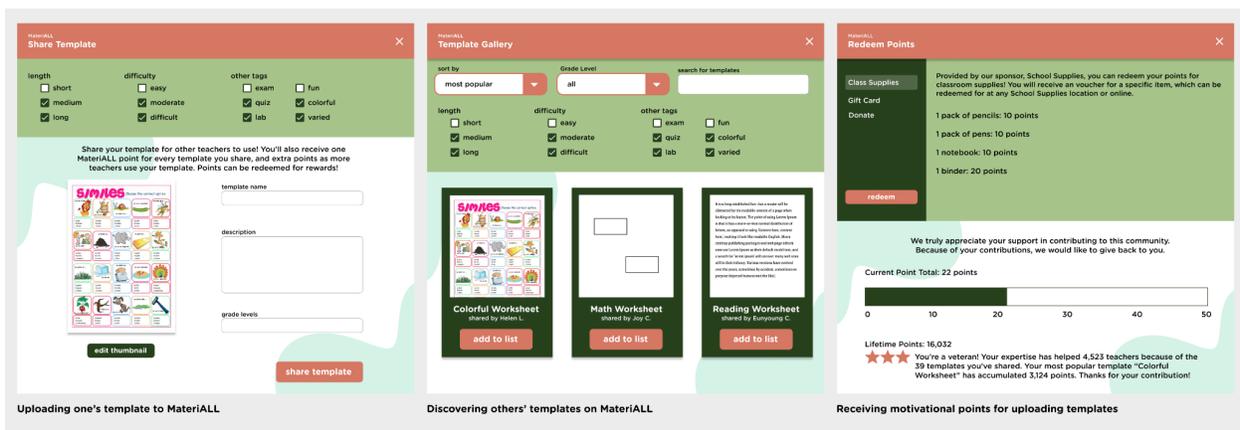


Figure 26: Uploading, browsing, and receiving motivation for using templates on MateriALL

Learning Objectives

When creating materials, one of the top priorities for teachers is taking into account learning objectives and standards. Our final deliverable implicitly assumes that their existing materials (slide decks) already meet all the desired objectives. To better meet teachers' needs in a product extension, we could explicitly keep track of learning objectives and standards for teachers. Using NLP technology, we could measure whether the created materials meet all the intended objectives. Therefore, we mocked up how MateriALL might support defined learning objectives and receiving feedback for worksheets (Figure 27).

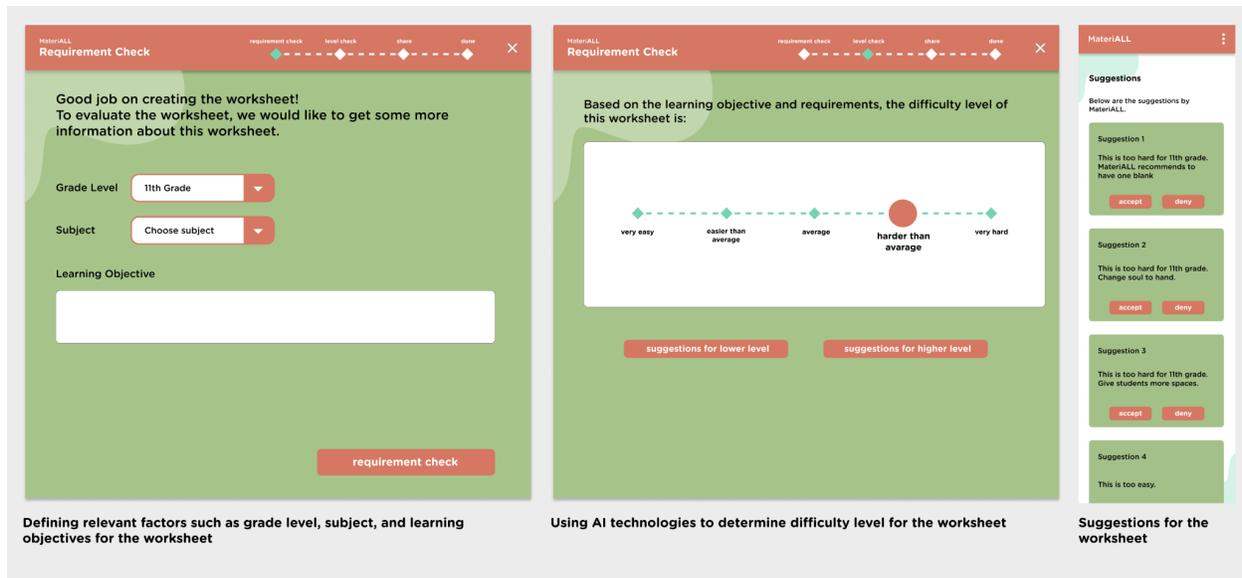


Figure 27: Potential screens for teachers who want to define, measure, and get feedback on the difficulty of their worksheets

Future Work

MateriALL can continue to be iterated and improved on. More research should be conducted to better understand teachers' needs and use cases. For instance, if teachers download and actually use MateriALL, a diary study could be helpful to understand how teachers would use the tool in a real-world setting. In addition, being able to recruit a more diverse sample of teachers for further user research could provide more insights, since our sample was limited to our network and social media.

In terms of technology, MateriALL's natural language processing could be further improved. Due to computing constraints, we were limited in the types of NLP technologies we could host on a web server. With access to more computation, MateriALL's auto-generated suggestions could be more robust and accurate.

As a whole, we can envision the possible future of MateriALL that goes beyond the use case we designed for. Our final project is a starting point that showcases the main concept in order to highlight our product principles and the findings from our user research. We focused

on generating a worksheet from slides, but MateriALL could potentially be a platform where any source (textbooks, slides, notes, etc.) can be turned into any material (worksheets, quizzes, flashcards, etc.), and creating any type of material would be considered a quick and easy task for teachers using MateriALL.

Acknowledgments

We would first and foremost like to thank all the K-12th teachers and educators who took time to sit down with us and provide insight into their work as well as feedback about MateriALL. **MateriALL was made with you and for you.**

We give our thanks to our advisor, Professor Kimiko Ryokai, and the School of Information's student affairs team for their advice and guidance throughout this project. Finally, we thank our family and friends for their overwhelming support throughout not just our final project, but our entire graduate school experience. Thank you!

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- [10] Google Docs for Developers. Google. <https://developers.google.com/docs/api/>

Appendix

First Round User Interview Guide

Before-Session Questions (~2 min)

- Hello, my name is [name], and my teammates [name 1] and [name 2] are joining us for note-taking purposes. Thank you for joining us for this interview. Today, we're going to be talking with you about how you plan lessons and create learning materials for the classroom.
- [Sign consent form if they haven't yet]
https://berkeley.qualtrics.com/jfe/form/SV_1HN8N5Dp6DwiPrM
- Before we begin, is it okay if we record this session? This recording will be private and only be viewed by our team members.
- [start recording]
- [If we haven't interviewed the participant before] Background questions
 - Could you share what subjects and grade levels you teach?
 - How many years have you been teaching?
 - What type of school do you teach at? (Public, private, etc.)
 - How many students do you have?

Process Questions (~12 mins)

- Can you walk me through your process of preparing a lesson?
 - How much time do you spend?
 - What resources do you use? Do you customize them?
 - How often are you building new material?
 - If you could do anything, what would make your work faster?
- How do you present concepts in the classroom?
 - What tools do you use? (if not mentioned)
 - How do you prepare materials for the classroom?
 - How do you make them?
 - How often do you use them?
- [If time] What do they do when they have like 10-15 minutes of extra time at the end of a class?

Material Questions (~11 mins)

- What kinds of materials do you use in the classroom?
- What are the things that you think about when you create materials?
- How often do you create physical vs. digital materials for the classroom?
- Can you give me an example of a material that you recently created?
 - Why did you choose that format/activity?
- Is there any difference between graded materials and ungraded materials when you create them?

- Can you share the deck you used in class and materials that you used on the same topic?
- Are there any other tools you use to create materials?

End-of-Session Questions (~5 mins)

- What is your biggest challenge/difficulty/pain point when it comes to planning lessons or creating materials?
- Is there anything we haven't covered that you think we should know?
- Do you have any questions for us?
- If you know any other teachers that would be open to chatting with us, please forward them our sign up form!
https://berkeley.qualtrics.com/jfe/form/SV_0kqSnD4BvpN2mnc
- Thank you so much for your time!

Adjacency Analysis: Creating Classroom Materials

[Math Goodies Worksheet Generator](#)

Description: Creates a math worksheet with different problems based on inputs such as number of problems, lessons to cover, etc.

Affordances:

- Very curriculum-forward – seems to be based on some kind of math curriculum
- Lots of inputs allow for customizability
 - Particularly like the idea of customizing the number of problems as well as display options

Lacking/Pain Points:

- While it's great that users can customize stuff like number of problems and display options, it's hard to figure out what can inform these decisions. What if we could use things like how long they want students to spend on the worksheet, accessibility, etc. to inform customization as well?
- The UI is very aged
- Math-only
- Can't import curriculum
- Everything happens on the left taskbar – maybe this is the easiest to onboard, but I assume teachers are used to drag-and-drop/more customization at this point (ie. PowerPoint), and a taskbar isn't going to cut it for flexibility

[TEFL.NET Worksheet Generator](#)

Description: A few existing templates for vocab/writing-based worksheets, with inputs that allow the user to change content.

Affordances:

- Activity-based – user chooses first the activity they'd like their students to perform (ie. word-scrambling, matching), then the content of the worksheet
 - This creates lots of diverse worksheets from, potentially, the same curriculum

- Essentially comes up with the rules for the teacher. The teacher just supplies the content
- Provides “good for” information that can help the teacher decide what worksheet to choose

Lacking/Pain Points:

- The UI is aged
- Form-based – can’t see what the worksheet is going to look like until you click a button
- Little customization in terms of lesson logistics – you don’t know how long it’s going to take, the font size, etc.

Canva

Description: A design tool with worksheet templates. Overall, more of a graphic design tool, but has teacher-specific functionalities.

Affordances:

- Lots of different templates, some that are specifically for certain subjects and lessons.
- Aesthetically-pleasing
- PDF download
- Very customizable – very similar to Figma in that every item on the page is an object, including text boxes

Lacking/Pain Points:

- While it’s customizable, the templates themselves are so “designed” that, once a user starts deviating, it’s hard to make it look good/pretty
 - This also makes it hard to start from scratch
- No curriculum import options – everything done by hand
- Not sure how print-able some of these pages are – they use a lot of colors and designs

PowerPoint

Description: usually for presenting slides, but according to several sources, it’s one of the most popular tools for worksheet creation.

Affordances:

- Very flexible – can move and drag things around easily
- Accessibility – most teachers have access to Microsoft Office and experience with its tools

Lacking/Pain Points

- No curriculum import options – the easiest way a teacher *could* do this would be just to use existing slides on PowerPoint, delete words, and replace them with blank spaces

Buying/Adapting from Non-Tech Resources

Description: common examples might be teacherspayteachers, borrowing from previous instructors, etc. Essentially, taking a class material a teacher has already made (ie. a worksheet), maybe buying it, and potentially editing it a little to meet needs

Affordances:

- Because the material was made by another teacher, there's some "merit."
 - If coming from a former instructor who taught the exact same lesson, even better! This would mean minimal need for editing
- Can specifically accommodate for particular needs like ELLs, length, standards, etc.

Lacking/Pain points:

- Costly, if not borrowing from a known peer
- Takes a lot of time to ask other teachers, make your own adjustments, etc.
- Might not perfectly align with your own curriculum – there might still need to be some customization involved
 - If the material is in the form of a PDF, customization suddenly becomes a huge pain.

Adjacency Analysis: Google Add-Ons

[Pear Deck](#)

Description: Google Slides Add-On that adds opportunities for student engagement on Google Slides.

Affordances: Hands-off approach to making slide decks more engaging for students, without a lot of work from the teacher. Automating engagement, essentially.

[NearPod](#)

Description: Google Slides Add-On that adds NearPod activities into Google Slides.

Affordances: Hands-off approach to making slide decks more engaging for students. Based on an existing product, so that there's some familiarity on both the teacher's side and the students' side.

[Scratch Blocks](#)

Description: Google Docs Add-On that adds images of a scratch block, or a set of scratch blocks, into the Google Doc.

Affordances: Automatically importing what is essentially code into a Google Docs. Scratch blocks can be large, unwieldy, and very different in different use cases.

[MathType](#)

Description: Google Docs and Slides Add-On that allows users to add mathematical and scientific equations.

Affordances: Great for a very niche group of users. Follows convention (ie. Latex), so there's not as much onboarding as necessary.

[Automagical Forms](#)

Description: Google Docs Add-On that converts questions into a Google Form in the same Google Drive.

Affordances: Makes use of the entire Google Drive ecosystem. Great example of NLP.

Concept Testing Guide

Before-Session Questions (~2 min)

- Hello, my name is [name], and my teammates [name 1] and [name 2] are joining us for note-taking purposes. Thank you for joining us for this interview.
- Today, we're going to be talking with you about how you think about what we present to you. There is no right or wrong answer and it will be just you telling us about your opinion.
- [Sign consent form if they haven't yet]
https://berkeley.qualtrics.com/jfe/form/SV_1HN8N5Dp6DwiPrM
- Before we begin, is it okay if we record this session? This recording will be private and only be viewed by our team members.
- [start recording]

Background questions (~7 mins)

- If we haven't interviewed them before:
 - Could you share what subjects and grade levels you teach?
 - How many years have you been teaching?
 - What type of school do you teach at? (Public, private, etc.)
 - How many students do you have?
- Can you walk me through how you create worksheets?
 - What kind of tools do you use when you create materials?
 - What do you use them for?
 - [optional, if time] What do you like about these tools?
 - [optional, if time] What do you dislike about these tools?

MateriALL Walkthrough (~3 mins)

- [Go through moderation deck]
https://docs.google.com/presentation/d/13zD0l6JM6_b-1VneZkgMbtXtxh1UDe6LNEp_mjysgdJY/edit#slide=id.g11a56cea8a2_0_10
- This is a tool that teachers can use when creating materials. It enables you to get information from your slides and create a worksheet.

General Questions about Concept (~10 mins)

- What are your overall thoughts on this tool?
- What are the reasons that you would use this tool?
 - What would you use this tool for?
- What are the reasons that you wouldn't use this tool?

- Is there another tool that would be more useful to you?
- If you would use this tool, what would you do with this doc after creating this?
 - Print? Add to Google Classroom?

Additional Questions (~6 mins)

- If you use this tool, how much customization would you do?
 - How much automation versus manual customization would you prefer?
- Are there any other resources that you would pull the curriculum from other than slide decks?
 - Are there any other materials that you would like to create using something like this besides worksheets?
- Is there anything else you would like to see in this tool?

End-of-Session Questions (~2 mins)

- Is there anything we haven't covered that you think we should know?
- Do you have any questions for us?
- If you know any other teachers that would be open to chatting with us, please forward them our sign up form!
https://berkeley.qualtrics.com/jfe/form/SV_0kqSnD4BvpN2mnc
- Thank you so much for your time!

Usability Testing Guide

Before-Session Questions (~2 min)

- Hello, my name is [name], and my teammates [name 1] and [name 2] are joining us for note-taking purposes. Thank you for joining us for this interview.
- Today, we will show you some screens and go through several tasks and also have some time for general feedback at the end. There is no right or wrong answer and it will be just you telling us your opinion.
- [Sign consent form if they haven't yet]
https://berkeley.qualtrics.com/jfe/form/SV_1HN8N5Dp6DwiPrM
- Before we begin, is it okay if we record this session? This recording will be private and only be viewed by our team members.
- [start recording]

Background questions (~3 mins)

- If we haven't interviewed them before:
 - Could you share what subjects and grade levels you teach?
 - How many years have you been teaching?
 - What type of school do you teach at? (Public, private, etc.)
 - How many students do you have?

MateriALL Tasks (~ 18 mins)

Please remember that we are testing the interface - not you. Honest feedback is the most valuable feedback since it allows us to find areas for improvement.

Also, as you are going through the tasks, it would be helpful to “think aloud”, and verbally say what you are thinking as you go through the tasks, so we can capture your thought process. [If the participant doesn’t understand: So as you're either trying to find a button or a link or content or whatever you're trying to do in that particular task, please actually say what is in your mind. “I'm looking for this, this is where I expected this to be but I'm not finding it,” this kind of stuff, so we can capture it on the audio track.]

Now, I will send the prototype URL via chat, please open it and on the top right corner, click options and fit width, so that you can see it in a better size. If you are done, please share your screen.

Let’s get to the tasks. This is a tool that teachers can use when creating materials. It enables you to get information from your slides and create a worksheet.

Task 1: Getting source slides

- What would you do to create a worksheet on the same topic of your presentation?

Task 2: Change source slides

- You got the slides, but you just realized that you pulled the wrong slides. What would you do?

Task 3: Detected content

- You want to make a worksheet question that test the definition of cognitive science. How would you do this task?

Task 4: Add True or False question

- In this scenario, you want to add a True or False question about the definition of cognitive science. You want to include a false statement to your worksheet by changing the last part of the statement “mind” to “soul”. How would you do this task?
- Copy and paste to chat: include a false statement to your worksheet by changing the last part of the statement “mind” to “soul”
- What would you do to add one more question with the same source sentence?

Task 5: Add fill in the blank question

- Now, for this task, I would ask you to do several things.
 - First, you want to create a fill-in-the-blank question about the sentence that you used in the previous task. You want to make “Cognitive science” and “interdisciplinary” blanks.
 - On this screen, what would you think of as clickable?
 - Copy and paste to chat: You want to make “Cognitive science” and “interdisciplinary” blanks.

- Second, you want to add this question to the answer sheet.
- And third, add a sentence after it that says “It combines fields like psychology, CS, etc.” How would you do this task?
- Copy and paste to chat: add a sentence after it that says “It combines fields like psychology, CS, etc.”

Task 6: Add multiple choice question

- In this scenario, you want to add a multiple choice question where you ask students to choose “mind” in the sentence you chose before. When you create this question, you want to have 4 options: mind, soul, head, and heart. How would you do this task?
- Copy and paste to chat: In this scenario, you want to add a multiple choice question where you ask students to choose “mind” in the sentence you chose before. When you create this question, you want to have 4 options: mind, soul, head, and heart. How would you do this task?

Task 7: Add a short answer question

- Now, you want to add a short answer question that asks students “what is cognitive science the study of?” And you want to give two lines for students to write their answers. How would you do this task?
- Copy and paste to chat: “what is cognitive science the study of?” you want to give two lines for students to write their answers.

General Questions (~5 mins)

- What are your overall thoughts on this tool?
- What are the reasons that you would use this tool?
 - What would you use this tool for?
- What are the reasons that you wouldn’t use this tool?
 - Is there another tool that would be more useful to you?
- If you would use this tool, what would you do with this doc after creating this?
 - Print? Add to Google Classroom?
- Is there anything else you would like to see in this tool?

End-of-Session Questions (~2 mins)

- Is there anything we haven’t covered that you think we should know?
- Do you have any questions for us?
- If you know any other teachers that would be open to chatting with us, please forward them our sign-up form!
https://berkeley.qualtrics.com/jfe/form/SV_0kqSnD4BvpN2mnc
- Thank you so much for your time!

Visual Style Guide

Typography

MateriALL uses Gotham Rounded as its main font. Gotham Rounded evokes a sense of playfulness that is reminiscent of the classroom. Its lines are also bold enough to promote readability for different kinds of users.

Gotham Rounded Bold

Gotham Rounded Bold should be used for main headings and interactive elements such as buttons and links.

Gotham Rounded Medium

Gotham Rounded Medium should be used for paragraph text and labels.

Color

Nicknamed "pale watermelon," MateriALL's color palette evokes lightweightedness to convey the product's hands-off approach to material generation, without sacrificing the delightfulness of play. Colors have been optimized for accessibility.



#D57762

Watermelon Red

To indicate selection, set at 50% opacity



#A3C088

Spring Green



#26401C

Forest Green

To indicate unavailability, set at 50% opacity



#74D3AE

Minty Fresh

For backgrounds, set at 30% opacity

Branding

MateriALL's branding can be found on its Google Marketplace listing, its Notion page, and its final writeup.



Titular Logo



Circle Logo

MateriALL's logo is a pencil, which is thematically related to its education-focused product space. The pencil is also made up of an "A" and two "L" letters, which together spell "ALL."

Design System

General Components

Input Forms

label

label

label

Minor Buttons

enter

enter

Link
label

Major Buttons

button

button

button

Tooltip

text

Fun Blobs



Sidebar Components

Header

MateriALL

Slide Navigator

change_source

What is Cognitive Science?
Cognitive Science is the interdisciplinary, scientific study of the brain.
It can involve lots of fields of study.

slide 2 of 20

Detected Content Selectors

Text

Text

Question Editor Components

Selections

Text

Text

Write my own option

Toggles

Sidebar

Original

True/False

Fill-In-The-Blank

Multiple Choice

Short Answer

add

Hoverable Text

text

text

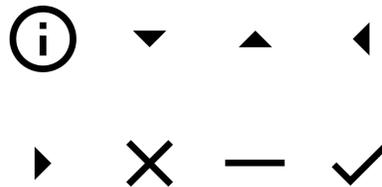
Previews

Worksheet Preview

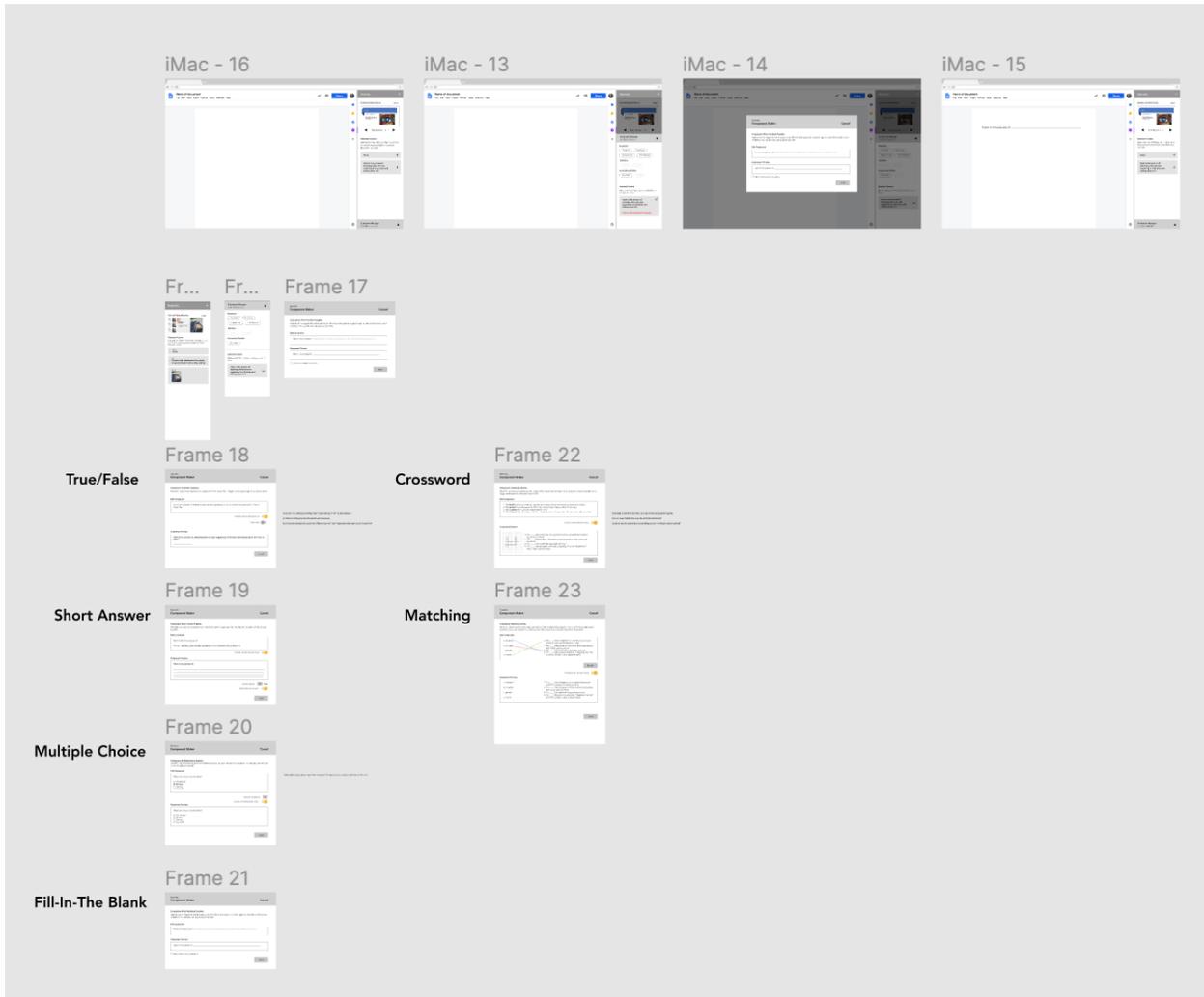
Answer Key Preview

Icons

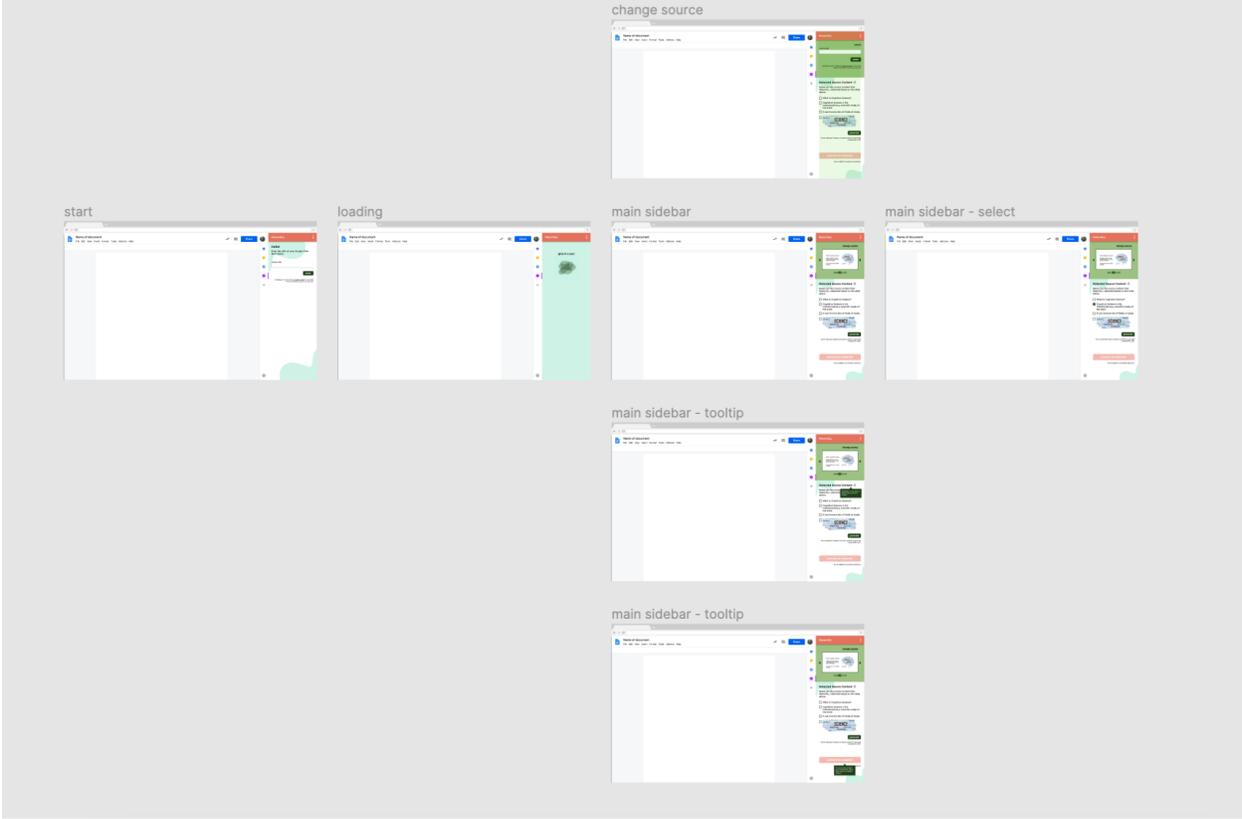
* Icons are from Google's Material Design Library



Mid Fidelity Screens (Iteration 1.4)

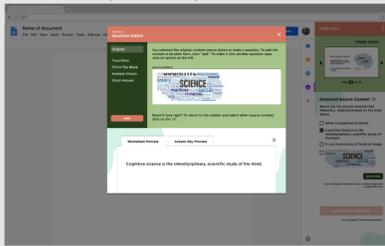


High Fidelity Screens (Iteration 2.8)



Sidebar

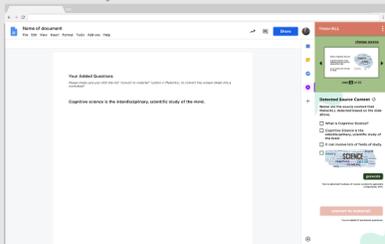
modal - home photo example



modal - home



tf - answer key



Modal (Original Content)

modal - tf - hover



modal - tf



modal - tf - false



modal - tf - false



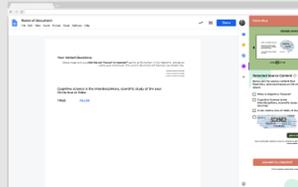
modal - tf - true options



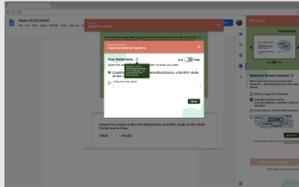
modal - tf - false



tf - answer key



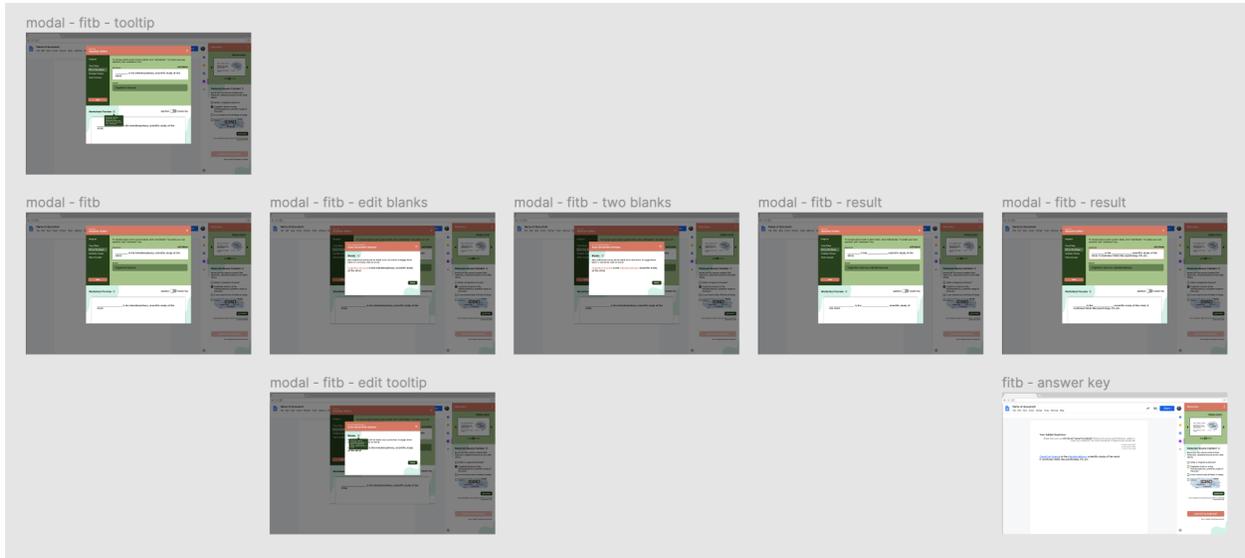
modal - tf - true options



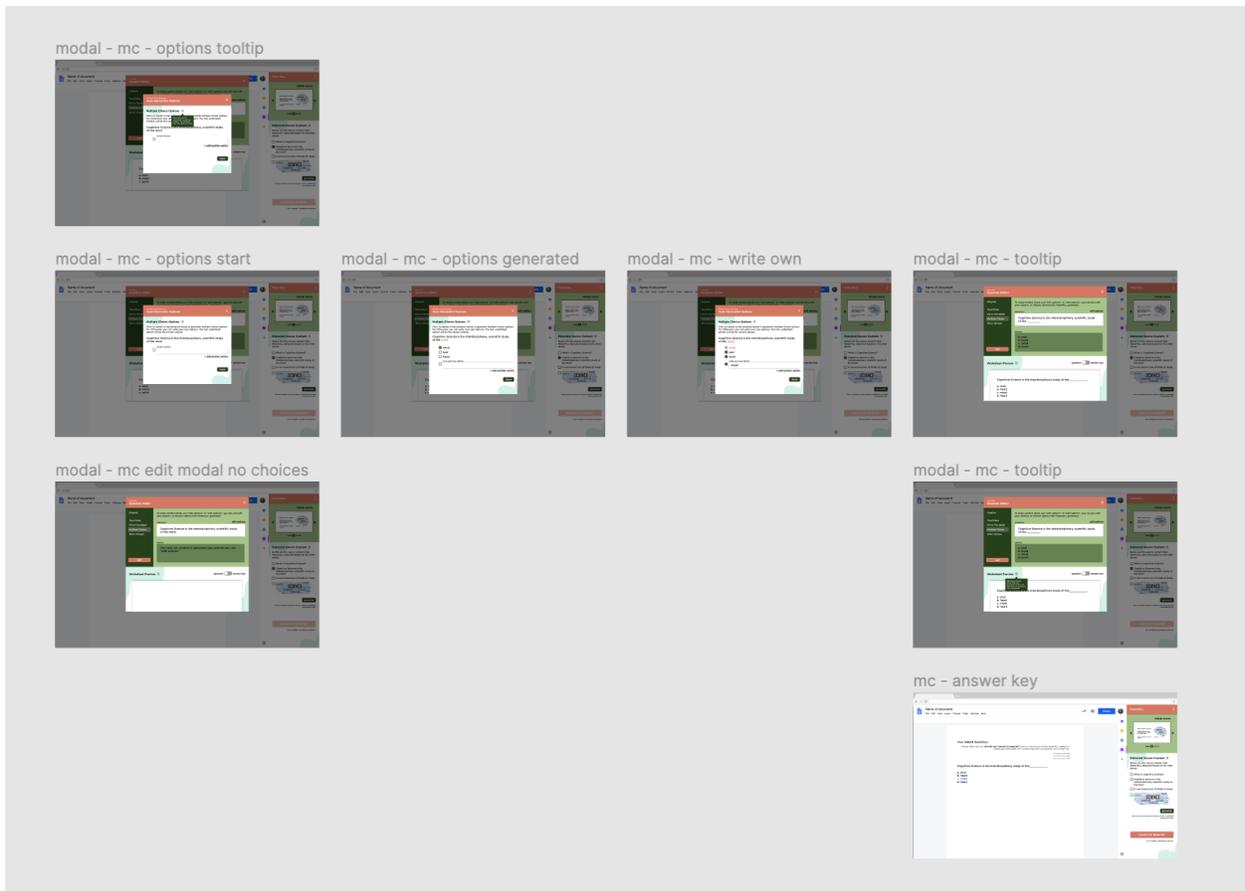
modal - tf - false



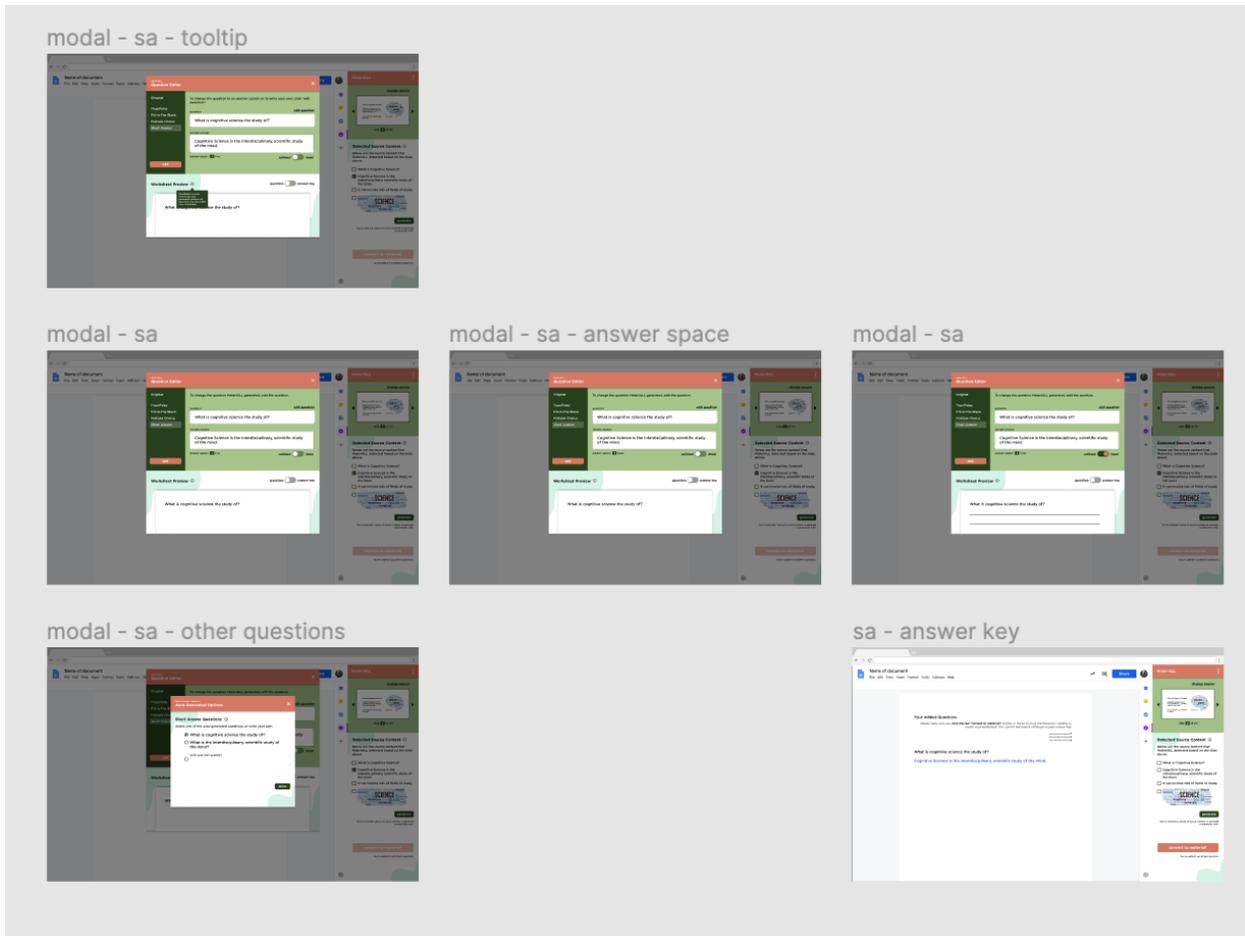
Modal (True/False)



Modal (Fill-In-The Blank)



Modal (Multiple Choice)



Modal (Short Answer)

Back-end NLP Documentation

Both input parameters and return output are JSON objects, which are outlined below.

Parameter Input

- `text` (string): the input text to auto-generate suggestions

Example:

```
{
  "text": "The Pacific Ocean is west of the United States"
}
```

Return Output

- `blank` (object): contains a suggestion for how to blank the sentence
- `false_sentences` (array): list of false sentences
- `mc_options` (object): for each word in the sentence, provides a list of similar words
- `text` (string): the original text passed in

Example:

```
{
  "blank": {
    "answer": "The Pacific Ocean",
    "beginning": "",
    "blank_sentence": "_____ is west of the United States",
    "end": " is west of the United States"
  },
  "false_sentences": [
    "The Pacific Ocean isn't west of the United States",
    "The Pacific Ocean is not west of the United States",
    "The Pacific Ocean differ west of the United States",
    "The Pacific Ocean is east of the United States",
    "The Pacific Ocean is west of the divided States",
    "The Pacific Ocean is west of the disunify States",
    "The Pacific Ocean is west of the divide States"
  ],
  "mc_options": {
    "Ocean": [
      "coral",
      "seas",
      "shoreline",
      "oceans"
    ],
    "Pacific": [],
    "States": [
      "legislatures",
      "jurisdictions",
      "nations",
      "countries"
    ],
    "The": [
      "this",
      "which",
      "one",
      "in"
    ],
    "United": [
      "unite",
      "cohesive",
      "unified",
      "disunited"
    ],
    "is": [
      "involves",
      "constitutes",
      "makes",
      "seems"
    ],
    "of": [],
    "the": [
      "this",
      "which",
      "one",

```

```
        "in"
    ],
    "west": [
        "southwest",
        "southward",
        "northeast",
        "southeast"
    ]
},
"text": "The Pacific Ocean is west of the United States"
}
```