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# SURVEY OF WIKIS AS A DESIGN SUPPORT TOOL

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## ABSTRACT
The use of design notebooks has long been common practice for engineers and designers. Wikis, freely editable collections of web sites, are becoming increasingly popular as flexible documentation and communication tools for collaborative design tasks. The main goals of this work are to better understand & improve wiki support for early design collaboration, and to give students hands-on experience in using wikis as a design tool. For this study, a wiki was provided for 500 engineering students (5 students per team) who worked to solve a challenging design problem. Surveys and interactive feedback sessions were used to analyze the wiki use upon completion of the design project. The results confirm that wikis are a useful and easy to use tool, but certain improvements would increase the utility of wikis for design projects. More features such as easier integration of graphics, metadata, and management options would improve the usefulness of wikis in design thereby improving shared understanding, allowing faster design iterations and better collaboration.

*Keywords: collaboration, ideation, conceptual design, design education, wiki*

## 1 INTRODUCTION
Technology is being developed at constantly increasing rates. While technological developments continually offer new opportunities for engineers, they also pose new challenges. One of the current challenges facing design engineers is the sharing of content often recorded in engineering design notebooks. While many information management products exist to track formal design information, few methods exist for easily recording and sharing informal information electronically [1]. During product design processes, expansive quantities of information are gathered from external sources and generated by design team(s). This information ranges from research on existing products to design sketches and analysis of ideas for new products being developed. While a multitude of resources are available for engineers to conduct necessary design tasks, there does not currently exist a suitable software product where information may be recorded in a centralized location and easily accessed during nearly all stages of the design process. Major advantages of tools such as wikis include the potential for increased reflection and development of shared understanding [2], improved concept generation [3], and easier design reuse in later projects.
The purpose of this experimental study was to evaluate the effectiveness of using a wiki as a tool for documentation during early stages of the design process. A wiki is an internet-based platform where users may easily update the contents of web pages without using formal programming languages like HTML. Wikis may be accessed by any users with sufficient access rights from any computer with internet access and a web browser. The term wiki was derived from the Hawaiian word “wiki-wiki” which means “fast” [4], and as the root of the name implies, one of the major advantages of wiki sites is that they are intended to be updated quickly and easily. Studies have been conducted concerning the use of wiki as an educational tool as well as a tool for project planning and documentation [5]. This study is unique in that a large number of participants used a wiki for a period of 3 months, and user feedback was gathered using a questionnaire from more than 500 wiki users. Also, the focus on the early stages of design allowed information to be gathered regarding the use of the wiki during the research, ideation and conceptual design phases.

## 2 BACKGROUND

With novel organizational approaches evolving in many companies, graduates face challenging work environments such as working in interdisciplinary and international project teams. One goal of the Karlsruhe Teaching Model for Product Development (KaLeP) [6], a model developed at the Institute of Product Development (IPEK) for educating product designers, is to improve the social, professional, and methodological competencies of graduates, which were cited as critical skills that employers indicated as often being inadequate among German university graduates [7]. These techniques were implemented in an undergraduate Machine Design course at the Karlsruhe Institute of Technology (KIT) in Germany.

The Machine Design course (MKL), consisting of approximately 500 students, is comprised of three parts: lectures, tutorials, and a design project. The lectures provide a theoretical foundation, while the tutorials and design project focus on applications of the concepts. For the accompanying design project, students form teams of five members in order to fulfill a small, but complex design task. Faculty, staff, and student assistants instruct and assist the students with the project work. Students receive individual feedback regarding performance and competence development, allowing them to evaluate their current state in the learning process. The workshop performance is assessed according to five fields of competence: professional, methodological, social, creativity potential, and the ability to implement ideas [8]. Recently integrated educational approaches (e.g. CDIO [9]) and publications (e.g. [10]) show that the success of design and development engineers is often attributed to the attainment of these types of skills and competencies.

To provide additional electronic documentation support for the design teams, and to expose students to a widely emerging internet technology, the use of a wiki was implemented into KaLeP as part of the Machine Design course. This research focused on evaluating the effectiveness of using wikis in design by observing the wiki usage during the design project and obtaining feedback from the students in the course.

The research project was a collaborative effort between IPEK and the Computational Design Lab in the School of Mechanical Engineering at Purdue University in the United States. During the course of this project, a student from Purdue University was embedded in the research project in Karlsruhe. Based on the preliminary findings from these studies, a design wiki is currently being implemented in the Purdue Mechanical Engineering Product Design and Innovation course (ME553) to allow for collaboration among distributed students.

### 2.1 Wikis

Due to the depth and breadth of knowledge required to develop a complex product in modern society, it is no longer feasible for an individual to work alone on a compound design project. This introduces a growing need for both effective communication practices and innovative knowledge management tools [11]. To date, three different generations of knowledge management approaches are being distinguished in literature. The first two phases were dominated by a strong belief in technical solutions for supporting decision making and the inclusion of all relevant knowledge in one system. In the third generation, the focus has shifted more towards the interactions between humans [2] as well as between humans and knowledge management systems. Wikis and semantic wikis are technologies that implement ideas of Web 2.0 [12] and the semantic web. These technologies both enhance (distant) interaction between humans via the internet and support the documentation and exchange of explicit knowledge as an easy to use publishing tool.

Wikis are software systems, which allow users to easily generate, publish and edit web pages, i.e. open content management systems. They are one way of enabling computer-supported cooperative work (CSCW) [4, 13]. The first wiki was implemented by Cunningham [4] in order to easily exchange information in a software development project. His intention was to create “the simplest online database that could possibly work”. Today, user-friendliness is still a central goal of wiki development. Two main elements of a wiki are the wiki pages and the wiki engine. The wiki pages are created and edited by users and contain the actual content and information which is displayed. The wiki engine is the software system, which provides the functionalities for viewing, editing and publishing the wiki pages on the internet. Wikis have become increasingly popular in recent years mainly due to the following advantages:

- Easy collaboration and formation of opinion
- Easy documentation and editing

- Easy cross-linking
- Simple structuring
- Full text search
- Open source

Wikis are currently being used in a wide range of applications. The most popular and well-known is the online encyclopedia, Wikipedia [14]. Various other groups and organizations use wikis for organization and communication purposes. In the professional sector, wikis are often used as collaboration tools in software engineering projects. Several references suggest wikis for application in product design and development [15, 16].

### 2.2 Literature Review

The collaboration and communication capabilities, the potential to serve as an interactive education tool, and the valuable documentation features make wikis an ideal platform for exploration in design team settings. First, because wikis are internet-based, a broad range of opportunities exist for collaboration and enhanced communication among design teams, especially teams which are geographically dispersed. Hill et al states that "communication in a social setting is often characterized as the creation of shared understanding through interaction among people" and that development of shared understanding is a key factor in high performing teams [2]. Because communication is a critical component in engineering design, it is important to continue developing and implementing tools that help to enhance team communication. Studies of wiki use in industry show that wikis can support collaborative design activities; however, drawbacks in the current state of wiki technology and wiki use inhibit more efficient use of this technology in design [15]. To improve the usability of wikis for design, a better understanding of these shortcomings is required.

Wikis are not only becoming increasingly popular in industrial applications as tools for supporting design but also as teaching tools in higher education, especially design education. At Stanford University, Chen et al explored how the use of wikis and weblogs in combination with the pedagogic approach of *Folio Thinking* in project based design courses can have a positive effect on students' knowledge and skills in engineering design [17]. After two ten-week quarters the students were interviewed; the survey results showed that wiki and weblogs can be suitable tools for design education, as they helped students to become more aware of their learning progress and design skills. While this particular study focused on the use of wikis and weblogs as a pedagogic tool, it provides strong support for improved design learning and enriched experience through wiki use.

Wodehouse et al. presented a study of groups of third year design engineering students who were using a particular Wiki engine, TikiWiki, for solving a rapid design task in ten teams of four students each in six weeks [3]. Results showed that using the wiki helped students to generate product concepts. The teams who interacted more with the stored information in the wiki generally achieved better results in the design project, even though transferring concept information into the digital domain was identified as a disadvantage which caused additional effort for the students. It was also suggested by the authors that adding and adjusting special wiki features for design and an improved understanding of information management in design processes may help to increase the usefulness of wikis for design and design education.

The notion that wikis are useful tools for higher education is not only supported by research in design education, but also through wiki use in education in other academic fields. Raitman et al. for example explored the use of wikis in Computer and Information technology course work at Deakin University in Australia [18]. Survey results showed that most users thought that wikis generally support collaboration but many wished wikis to be easier to use and to provide more features. This implies that the usefulness of wikis for applications in industry and education may be significantly increased, but a better understanding of the processes and user needs for certain applications like design and design education is needed.

In general, wikis seem to be a useful tool for design and design education. However, there is substantial room for improvement in wiki technology and usage. A thorough analysis of current wiki use in design and a better understanding of the design activities that should be supported by wikis are needed to design new and improved design wiki features and to provide more specific usage recommendations.

## 3 PROJECT DESCRIPTION

During the 2008 summer semester, the design project assigned to students in the Machine Design course at the University of Karlsruhe was to design a pair of legs for the next generation of humanoid robots of the collaborative research centre (*Sonderforschungsbereich*) 588 (SFB588). ARMAR III is one of the current full-size humanoid robots of the collaborative research centre 588 which was designed to closely cooperate with humans [19]. The neck, torso, arms and holonomic locomotion platform of ARMAR III were designed and built at the IPEK Institute of Product Development in cooperation with the SFB588. To increase the anthropomorphic features and widen their range of applications, the SFB588 plans to build legs for the next generation of humanoid robots. As this is a challenging but realistic project, it was provided as the design task for the Machine Design students.

In general, the students enrolled in the course did not have any prior experience in engineering design projects, and had not previously been introduced to formal design process methodologies. Although extensive guidance is not provided in terms of a specific design process, the project is broken down into three phases. After each phase, the student teams present their design solutions and discuss their progress with student tutors and teaching assistants. During the first phase, students gather, synthesize, and present information about the state of the art in actuators, sensors, transmission elements, and bipedal locomotion for humanoid robots. As each team was only required to investigate one of those four topics, approximately 125 students researched each topic. During the second phase, students generated ideas and concepts for the design of robotic joints, utilizing the findings from the first phase. During the final phase, students conducted the embodiment design for a pair of humanoid robot legs.

## 4 RESEARCH APPROACH

To begin exploring the use of wiki as a design tool, a DokuWiki [20] (the type of wiki engine) was configured for the students to use during the project. DokuWiki was selected based on several positive features such as a convenient overview of contents, simple editing syntax, user and group access controls, and flexibility due to several extensions that enhance functionality. In order to give students awareness of the importance of knowledge management in collaborative product development, a brief introduction to wikis and ways in which wiki can support collaborative design was presented at the start of the course. Each student was provided a unique username and password which was required for them to log-in and edit the wiki pages. Every team was provided two different namespaces, or groups of wiki pages. One namespace remained private throughout the design process, meaning only the team members and wiki administrators could access the contents. The other namespace of each team contained the research information recorded during the first phase of the design. The research namespace was made public to all other teams after the first phase. Figure 1 shows an example page as a result of the first project phase.

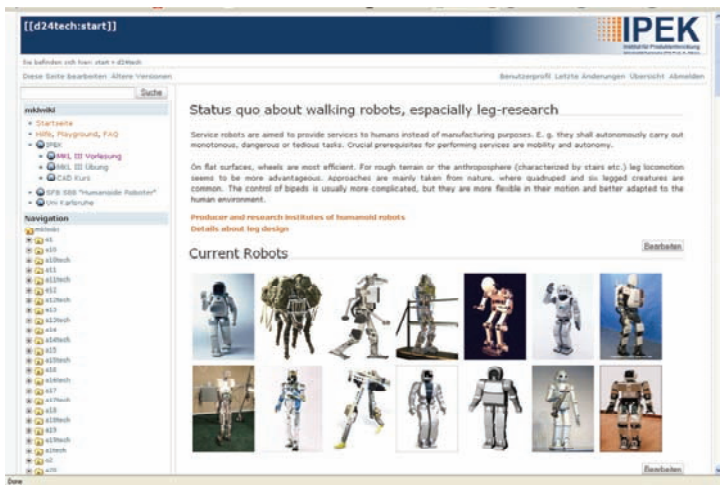


*Figure 1: Example wiki page for research on humanoid robot legs created by students*

Because all students could access the results of this research phase, an expansive common knowledge base was created by the students, which could be used for the remaining project phases. For the second and third project phase each student team documented their project information in their private team namespace. At the end of the course a questionnaire survey was conducted to obtain user feedback.

### 4.1 Research Objectives

Prior to generating the questions for the survey, three main objectives were determined to help focus the scope of the work. The three objectives of the questionnaire were:

1. *Determine at what points in the design process the use of the wiki is most effective.*
   Because students in the MKL course have not been exposed to specific design processes and do not know "stages" of design, the questionnaire was used to determine at what points in the design process (based on the course phases) the wiki was used most (i.e. at what points in the design did students add the most content to the wiki, update it more frequently, etc.). By looking at the patterns of usage, we hoped to transfer the findings into the stages of design for which the wiki is most effective.
2. *Determine the most effective features of the wiki for use in engineering design projects.*
   We hypothesized that students would find ways to utilize tools and features of the wiki that were most beneficial to them, and would likely not use features that they did not find convenient or beneficial.
3. *Determine features not currently part of the wiki that would be beneficial to engineers.*
   We also projected that, after using the features that were available with the wiki, students would be able to suggest features and tools of the wiki that were not available which would have been helpful for them during their design project. Because this was an exploratory study, we hoped to obtain the initial reactions of the students after using the wiki, and form a foundation to later explore specific aspects of ways in which wikis may be utilized more in depth during the design process.

### 4.2 Data Collection

A questionnaire survey was selected as the method of evaluation for the wiki. The primary reasons for using a questionnaire are that they provide feedback directly from the users, and they allow for the collection of large amounts of data to be used for analysis. Although the students are not experts in design, it was decided that they would provide a suitable platform for evaluating the use of the wiki because they are familiar with computers and would be using computers frequently during the design process.

The questionnaire contained 39 questions with Likert Scale responses (scale of 1-5, 1 = strongly disagree, 5 = strongly agree), 2 questions with three choices each, and 3 open response questions where students could freely answer by writing in their thoughts. The survey for collecting feedback from the students was broken down into four main categories: previous experience, usability of the wiki, organization of the wiki, and use of the wiki for design. A separate section of the survey was dedicated to open ended questions to allow students to freely respond with their inputs regarding the use of the wiki.

The questionnaire was administered in German for the majority of the students in the course. Several exchange students also participated in the course; an English version of the survey (using the same questions and structure) was provided for the students of the teams with English-speaking exchange students. The questionnaire was conducted during the final design review of the Machine Design course. Student tutors (or Teaching Assistants) distributed and collected the questionnaires from each of the students on the teams for which they were responsible. Interactive feedback sessions were also conducted with some of the students to gather feedback about the usability of the wiki and its applicability to design.

### 4.3 Data Analysis

Results from the surveys were entered into a spreadsheet for initial analysis. A statistical analysis software (SAS) was then utilized to further determine significant findings among the survey responses. Initial analysis of the data included determining percentages of the total responses that agreed, disagreed, or responded neutral to each of the questions. Mode responses for each question were also used to determine the general opinion or response for each question. As a note, the percentage results

are based on the number of responses to the question rather than total number of responses. All questions had a response rate of at least 91%.
Statistical analysis included determining significant correlations between each of the questions. While correlation does not imply causality, hypothesis tests were used to determine whether or not relationships between certain questions were significant. The three most significant correlations are presented in the Discussion section along with the p-value ($p<0.05$ for 95% confidence level). By considering the question combinations that appear to have significant trends, additional tests may also be conducted to further explore the relationships and conclusions regarding the use of wikis in for engineering design projects.

### 4.4 Limitations of Work

Because the described study was conducted in an educational environment, a few discrepancies from an industrial setting are worth mentioning. First, the participants were students in their second year of studies in Mechanical Engineering and are therefore novice designers. While the students' lack of design experience provides them with a different perspective on using the wiki, the results from this study may not be applicable to experienced design teams. Also, the motivation of students (achieving high grades) is different from the motivation of practicing designers (develop quality designs). Although the project was relatively complex compared to other educational design projects and lasted for an entire semester, most design projects, e.g. in the automotive industry, are much more complex and often take several years to complete. Finally, the team structure was relatively homogeneous in this academic environment, while design teams are often much more dynamic in industry. Information gathering via survey only enabled the capture of certain criteria, but was selected as the most feasible mode due to the high number of participating students.

## 5 RESULTS

Wiki can be a useful tool for engineering design projects if it is efficiently utilized. It may improve communication among team members, help teams stay organized, and provide a common location for sharing ideas and electronically documenting design information. The questionnaire responses provide the majority of the findings from the experiment. Discussions with the students, however, provided useful feedback that will also be presented.
The depth or extent to which wiki sites were used throughout the design process varied among the teams. Some teams used the wiki mostly for team planning and communication (recording meeting minutes, posting meeting times, etc.), while other teams continually updated their sites as they generated new ideas, found important information, and made decisions regarding their design. Results from the analysis of the questionnaire responses are presented according to the corresponding sections of the surveys. (NOTE: a "Q" followed by the question number indicates the question number corresponding to the discussion; e.g. (Q12) indicates question 12 from the questionnaire.)

### 5.1 Previous Experience

The "Previous Experience" section of the questionnaire was intended to gather background information about the students' prior usage of online wikis. A large majority (87%) of the students indicated that they had used wikis before as a reader (Q3), which supports the assumption that they were at least somewhat familiar with the wiki concept prior to starting the MKLIII project. However, only about half of the students indicated that the possibilities of wiki were well known to them before MKLIII (Q1), and approximately 86% indicated that they had not used wikis before as an author (Q4). While the students may have been familiar with the concept of the wiki, they may not have used it extensively for this project because they were not aware of many of the features, and because they did not have much previous experience editing and contributing to a wiki.

### 5.2 Usability

In general, the students seemed to find the DokuWiki relatively simple to use. A breakdown of the responses is shown in Figure 2.

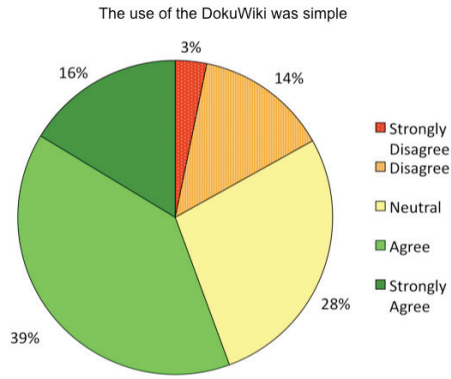


*Figure 2: Results for question 9*

Half of the students said that they were able to easily find information within their own team's namespace, while 25% said they were not (Q11). The majority of the students (71%) responded that they could not quickly find information in other teams' namespaces. A more detailed breakdown of these responses is provided in Figure 3.

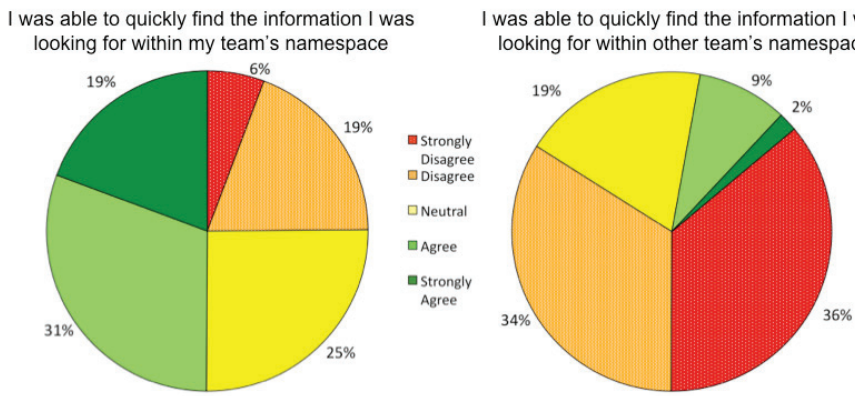


*Figure 3: Results for questions 11 and 12*

These responses may be an indication of two main factors. First, because a formal structure or template was not provided, each team chose to organize their information differently. Without an indication of how the information was organized, it was difficult to find information within the namespaces of other teams. Also, only 37% of the students said that they accessed the pages from other groups to gather information (Q30). It is unknown however, whether the students did not access the other pages because they could not quickly find information, or whether they assumed that they would not be able to quickly find information, and therefore did not make an effort to access the pages of other teams.

Only 20% of the students said that they found the information from other groups useful (Q31). This may indicate that students did not necessarily trust the validity of the content posted on the pages of their peers, or it may indicate that a better search tool and/or a standard layout for the research design sites would make the information more accessible and useful. One major reason the students did not find the web pages from other groups useful is probably because they felt they were not able to quickly and easily find information on the other teams' pages. Although a large percentage of the students did not access the technology review pages of the other groups, those who did access them generally responded that they found the pages from other teams useful.

### 5.3 Organization of the Wiki

It was hypothesized that the manner in which teams chose to organize their sites would be related to how easily they would be able to find information, whether or not they would use the wiki to document design information, and whether or not it would be a useful tool for communication among team members. While not a majority in either case, approximately 44% of the responses indicated that it was easy to structure the wiki pages to organize information (Q23) and 40% said they were able to structure the site as desired (Q24). Students may have thought that while it was not technically difficult to structure the pages (e.g. adding links, creating a main page, etc.), it was difficult to structure the contents of the wiki so that team members could easily access, update, and add information to their namespace. Almost 60% of the students felt that the text and image formatting options were sufficient for the purposes of the project (Q25). The organization and usage of the wiki may have been influenced by the motivation of each team.

Another interesting aspect of the wiki is its use for communication. While 71% of the respondents said they most often worked with the wiki at home (21% said at the university) (Q41), only 28% said they used it for communication with their team (Q15). This likely indicates that students used the wiki to record information such as background research when working with the wiki alone, or that individuals may have documented information after the team had already met and communicated their ideas to each other. Teams used the wiki for recording results of their discussions as well, as evidenced by the charts provided in Figure 4.

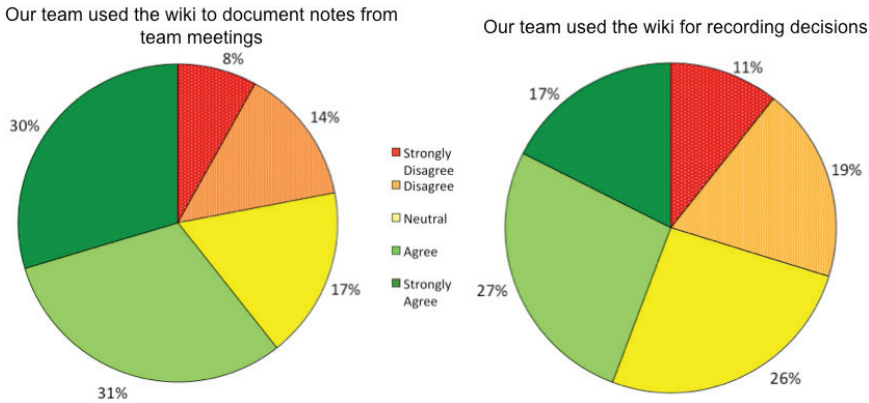


*Figure 4: Results for questions 19 and 21*

Finally, a large portion of the students (62%) indicated that more than one person from their team updated the wiki (Q26), which supports the collaborative and team aspects of using the wiki for documenting team decisions, research information, and design ideas.

### 5.4 Use of the Wiki for design

Previous research showed that wikis have potential to improve conceptualization in early design [3]. In this study, students may not have found the wiki particularly useful if they were unaware of the ways in which they could use it to their advantage. While 46% of respondents said they imported sketches of their conceptual/principle designs (Q29), only 26% agreed (while 45% disagreed) that it was easy (Q28). Students found it difficult and time consuming to record conceptual design ideas largely because of the required formatting. Students generally sketched ideas on paper, and therefore needed to scan the picture (or take a photo and upload it to the computer), import/upload it into the wiki, and adjust the sizing. To upload many sketches and track conceptual designs, this process can be quite cumbersome and time consuming. Although it is relatively easy to use for documenting text, wikis are not yet an efficient means for documenting other design information such as sketches, tables, block diagrams, function diagrams, etc.

Because the wiki was relatively easy to update and format using text, the majority of the students (73%) responded that the wiki was most useful for recording information during phase one of the project (Q40). More students agreed that they would likely use a wiki again in future engineering

design projects than those who liked using the wiki and who found the wiki to be a useful tool for the project. This provides strong evidence to show that while the wiki may not be developed enough at this point to be the "ideal" engineering design documentation tool, it is a good starting point due to many of the positive features. The findings from these questions are presented in Figure 5.

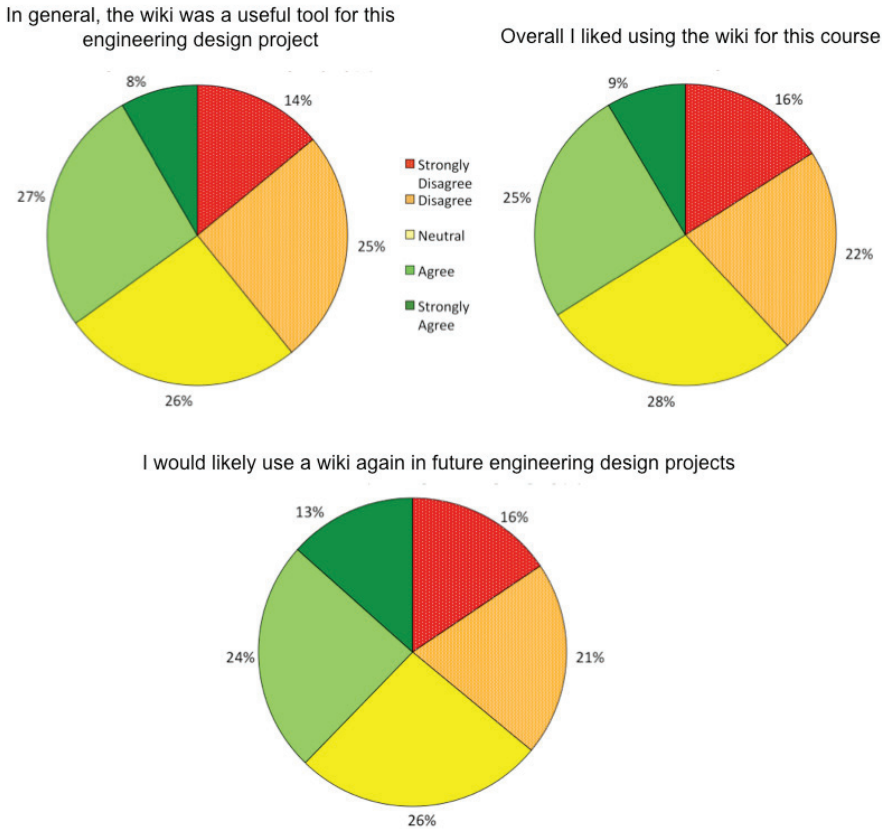


*Figure 5: Results for questions 37, 38, and 39*

As shown in the results above, students provided approximately equal responses between "agree" and "disagree" for questions 37, 38, and 39. For this course, it appeared that students did not seem to find the wiki necessary for the design work they were conducting. Because students were co-located and could easily meet, they did not see the need to use the wiki. They were able to discuss ideas in person and found it easier to use pencil and paper to sketch and note their ideas rather than using the wiki. Distributed teams that are not able to easily meet in person would probably find the wiki more useful for sharing and communicating ideas as well as documenting information.

### 5.5 Open Response and Interactive Feedback

A broad range of opinions was also gathered through discussions with the students. Similar to the findings from the survey responses, some students found the wiki quite useful for this design project, while others found it too limited in its capabilities. One of the main complaints about the wiki was that it did not allow documents to be uploaded, only images. While this is clearly a desired feature for an engineering design documentation wiki, it was not feasible for the institute to provide this feature due to the large number of student teams and limited hard disk storage on the servers hosting the wiki sites.

Students also commented that they did not think recording information in the wiki was really necessary for this design project, but they felt the wiki could be useful for a larger-scale engineering

project. Students found that email was easier (for communication) than using the wiki, and that paper sketches and documents were easier to maintain than scanning hand sketches and uploading them to the wiki. They also noted that while it is a good tool, they think it would be more useful for geographically dispersed teams (teams that cannot easily meet in person). If it were to be used for a larger-scale project, students stated that more features would be needed, and it would need to be easier to use. Several additional features suggested by the students both during discussions and in the free-response portion of the surveys include:

- Option to receive e-mail notification when wiki is updated
- Calendar
- Easier way to add tables
- Chat function
- Features found in "group" sites that enhance planning and communication
- Better search function
- Easier uploading of hand sketches
- Ability to sketch on pictures/ edit images from within the wiki

Finally, students also expressed that they would have liked to see some example pages, and have a better description of how the wiki could be used for engineering design projects. Although sample pages may be provided for students in future projects, it was predetermined prior to the start of this work that example pages would not be provided to avoid the misconception that their wiki should be managed or organized a certain way. By not providing example pages (although samples of the formatting syntax were provided) the structure was left open to the students' discretion, allowing them to decide what to include and how to document their information. The intent was to explore the ways in which students chose to use the wiki without being biased by example pages.

### 5.6 Discussion

Due to a few limitations of the work, as previously discussed, it is difficult to generalize the results from this exploratory study. However, several key findings are worth discussing in further detail. One key finding is that the simplicity of the tool or system may contribute to the utility of it when used in specific applications. From the survey results, it was found that, in general, students who found the use of the DokuWiki to be simple (Q9) and who agreed that the issues concerning the wiki were easy to resolve (Q10) also found the wiki to be a useful tool for this engineering design project (Q37) ($p<0.0001$). Students who found the wiki easy to use were probably more likely to use the wiki, and therefore found it to be a useful tool. The user-friendliness of a documentation tool is especially important in the modern technology era. A likely reason that massive quantities of early design information are lost is because technologies do not currently exist which allow users to easily record and later locate the data. Wikis appear to be a highly feasible solution towards achieving this goal.

Next, results from the surveys also support the use of wiki for collaboration and team/group work. Based on the responses, the teams who had more than one person using the wiki (Q26) seemed to find it a useful tool (Q37), while often teams who said only one person managed the wiki did not seem to find it a useful tool for this engineering design project ($p=0.0129$). This supports our hypothesis that wiki can be a useful tool for collaboration in design. It also provides some initial evidence to show that wikis are more useful as a team collaboration tool rather than an individual repository. It does not take into account, however, the types of information contained in the wiki, the frequency of usage, or the total number of contributors.

Finally, those who felt that the wiki enhanced communication among their team (Q17) were more likely to agree that the wiki was a useful tool for this engineering design project (Q37) ($p<0.0001$). This finding also provides support for the idea of using wiki as a collaborative design tool. Students in the course, while able to access the wiki from anywhere, had the opportunity to meet face-to-face on campus. The impact of the face-to-face meeting in conjunction with the wiki is not clear at this point, and it is likely that different results would be found if the wiki was used for geographically dispersed teams. The high correlation however, provides strong evidence that the communication aspect may be a strong predictor for the actual utility of wiki as support tool for engineering design. An area that remains to be explored are the specific ways in which wiki can serve as a communication tool for design, and how the dynamic flux of information contributes to the creation of shared understanding among design teams.

## 6 CONCLUSION

In general, while there are some specific features (or lack of features) of the DokuWiki that hindered the full potential use, the underlying concept of using wikis in design is strong. Wikis do not require specific software to be installed locally, they can be accessed from any computer with internet access, and they allow quick updates which may then be viewed by other team members.

From this work, the wiki was found to be most effective for students during the first phase of the project (Technology reviews). The most common uses of the wiki for this design project were to:

- Document meeting notes
- Record decisions
- Collaborate with team members
- Record design requirements
- Document research findings

Students generally found the wiki to be easy to use and a helpful tool for the project. For the wiki to be a more effective tool for engineering design however, more features that correspond to specific design activities are necessary. A few suggested improvements include:

- Ability to upload multiple file types
- Easier methods for recording conceptual design ideas such as an integrated sketching tool
- Better tools for project planning and management (calendar, task manager, etc.)
- Different means for structuring content so that information contained in the wiki is organized, and topics may be located quickly and easily

Variations in the design activities that students performed during the course versus what they recorded in the wiki were observed. For wikis to better serve as both documentation and collaboration tools for design, they should allow for a more seamless transition between the paper space and the digital domain to better serve as an electronic design notebook. Additional features should also be provided to improve the communication and shared understanding between team members. Because wikis can also serve as a collaboration tool for design teams which are geographically dispersed, the wiki concept has high potential to serve as an effective engineering design documentation and communication tool.

## 7 FUTURE WORK

Future work for wikis as a design support tool includes further exploration of the ways in which wikis can be used to improve communication and documentation in design. By determining ways in which designers use the wiki to document ideas and information, we hope to gain insight into the various ways that shared understanding is established. By implementing existing technologies that allow for easy transition of data from a paper notebook to the digital domain, we hope to gain insight into the different applications of wikis for recording and sharing information among design teams.

The foundational experiences from using the wiki at KIT are being utilized to guide the current wiki research at Purdue. Currently, students in the Purdue Product Design and Innovation course are using a wiki developed by GlobalHUB [21] to collaborate and document information for a design project. Continued research is also being conducted at KIT with the integration a Microsoft Sharepoint environment in the Machine Design course. MS Sharepoint provides wiki functionalities along with various other features, e.g. managing documents, calendars, and tasks. MS Sharepoint also allows for easier what-you-see-is-what-you-get (WYSIWYG) editing as opposed to the required syntax of DokuWiki. Students will be able to structure and access the wiki content through social bookmarking. Similar questionnaire surveys and observations will be used to collect feedback. By providing different features and modifying the survey questions, additional data and more thorough analysis will help to advance the investigations of utilizing wiki as a communication, documentation, and education tool for design.

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