ENHANCING TECHNICAL ACCESSIBILITY: AI-POWERED CONVERSATIONAL ASSISTANT AND AUGMENTED REALITY-ASSISTED 3D PRINTING SOFTWARE FOR NOVICE USERS

BY

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THESIS

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ABSTRACT

The growing popularity of 3D printing technology has revolutionized the manufacturing industry by enabling manufacturers to produce complex designs and prototypes rapidly and efficiently. However, the complexity of the software user interface and the printing process itself poses significant challenges for novice users like 3D printing enthusiasts, design students, etc. This paper discusses the current challenges in 3D printing and highlights the need for more accessible and user-friendly tools for enhancing 3D technology accessibility. To address these challenges, this paper proposes a software solution that leverages augmented reality (AR) and artificial intelligence (AI) technologies to create an interactive and user-friendly software called "3D PrintEasy". This guides novice users through the 3D printing process and provides real-time feedback to improve their prints. This software also includes a conversational assistant that can answer user questions and provide helpful tips. This paper contributes to the growing body of literature on the integration of AI and AR technologies in the manufacturing industry and emphasizes the importance of considering the needs of beginners when designing software solutions for 3D printing technology. The proposed software has the potential to greatly enhance the accessibility and usability of 3D printing technology for beginners and revolutionize the way beginners learn and interact with 3D printing technology.

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CHAPTER 1: INTRODUCTION

3D printing technology, also known as Additive Manufacturing (AM), resembles the process of printing computer text on paper, as it constructs objects from digital information (Michalski & Ross, 2014) using thermoplastic materials including acrylonitrile butadiene styrene (ABS), polylactic acid (PLA), polycarbonate (PC), and polyether imide (PEI) (Duty et al., 2018). There are two popular types of 3D printing technology, FDM (Fused Deposition Modeling is a method of material extrusion whereby a 2D layer is created by melting plastic filament and extruding it through a nozzle, as a print head traverses along two distinct axises and SLA (Stereolithography is renowned for producing precise, isotropic, watertight prototypes and components with intricate details and smooth finishes using advanced materials (*Guide to Stereolithography (SLA) 3D Printing | Formlabs*, n.d.)).

3D printing is a revolutionary manufacturing process that has gained popularity due to its accessibility and versatility (Shahrubudin et al., 2019). With 3D printing, manufacturers can easily create complex designs and prototypes at a low cost, and with rapid turnaround times (MacDonald et al., 2014). This technology has become a game-changer in the some manufacturing industry making it possible for factories to quickly and efficiently manufacture products with minimal waste. Beyond industrial applications, 3D printing has also made its way into schools (Ford & Minshall, 2019), personal studios, and other settings, making it possible for everyday people to create their own products. However, while the accessibility of 3D printing is great, it's not without its challenges.

One of the biggest challenges with 3D printing is the complexity of the software user interfaces. Most 3D printing software is designed for professionals and can be difficult for beginners to use (Ludwig et al., 2017). These software tools contain many industrial professional terms and parameters that can be overwhelming for someone just starting with 3D printing. Beginners often need to spend a significant amount of time learning how to use these tools, which can be frustrating. In addition to the software challenges, 3D printing printers themselves can also be problematic. There are many issues that can arise during the printing process, such as filament shortages, nozzle blockages, and other problems (Mueller et al., 2020). These issues can be difficult for beginners to solve on their own, which can discourage them from continuing with 3D printing (Oropallo & Piegl, 2016). Despite the challenges, 3D printing is an exciting technology that is radically changing the manufacturing landscape.

To address the challenge of making 3D printing technology more accessible and to increase the market volume of 3D printers, researchers have been exploring ways to enhance the capabilities of 3D printing digital interfaces (Beltagui et al., 2020). This involves leveraging intelligence, connectivity, and analytics to improve manufacturing strategies. One critical area of focus is the development of sensing and feedback mechanisms that enable users to quickly identify, assess, and address problems during the printing process (Deneault et al., 2021). While these efforts are promising, many studies have focused primarily on improving the efficiency of the printing machine and have neglected the issue of technology accessibility for beginners. To make 3D printing more accessible, it is essential to consider the needs of beginners and provide them with user-friendly tools that are easy to understand and use. Additionally, efforts should be made to provide education and training to help beginners overcome the steep learning curve that comes with using 3D printing technology.

At the same time, the Industrial Revolution 4.0, which centers on the increasing prominence of digitization, automation, and the advanced implementation of Information and

Communications Technology (ICT) across multiple sectors (Alaloul et al., 2020), fosters the development of emerging technologies, particularly augmented reality (AR, as shown in Fig. 1). AR can improve real-world interactions by projecting virtual objects onto the physical environment (Rhee et al., 2020). By this means, it enables the visualization of 'cyber-physical' products in a number of dimensions to facilitate thorough observation and understanding by users (Şahinel et al., 2021).

Figure 1. Augmented Reality Tech (*Augmented Reality Support - Bring Remote Support to a Whole New Level*, n.d.)

Meanwhile, recent advances in AI conversational technology have led to the development of chatbots, virtual assistants, and other conversational agents that can interact with users in natural language (Mekni, 2021). In the context of 3D printing, AI can be leveraged to provide intelligent guidance and assistance to beginners who may lack technical expertise. For example, ChatGPT, a large language model trained by OpenAI, can answer users' questions and provide helpful tips on 3D printing techniques and troubleshooting. By integrating these AI-powered conversational agents with AR technology, the proposed software development discussed here has the potential to greatly improve the accessibility and usability of 3D printing beginners.

The proposed software includes a conversational assistant that can answer user questions and provide helpful tips along the way. Overall, the integration of these technologies has the potential to revolutionize the way beginners learn and interact with 3D printing technology.

CHAPTER 2: RELATED TECHNOLOGY

The growing flexibility and efficiency of user interface and experience (UI/UX) design has opened new possibilities for software development that can be tailored to the needs of users with different professional skill levels and backgrounds. The rapid advancement of AI has enabled the development of conversational agents and virtual assistants that can interact with users in a more natural and intuitive way, further improving the user experience, which will be introduced as follows. In general, the integration of AI-powered conversational agents and AR technology with 3D printing has the potential to revolutionize the way people interact with 3D printing.

2.1 Augmented reality technology

Because of the diversity of AR solutions for manufacturing purposes, it is rapidly developing in industrial environments, for example, in the fields of visual inspection equipment functionality or manufactured products for proper operation, using front-end interactive screens (e.g., headsets, smart glasses, etc.) in bug tracking and assembly assistance on a large scale (Kolla et al., 2021). A number of studies have shown that AR can not only rapidly improve the labor skill proficiency of workers but also reduce operational errors caused by human factors in production, which leads to a substantial increase in overall manufacturing efficiency underutilizing the visualization ability of AR tech (Tavares et al., 2019). For example, visualization of product production standards and work specifications based on AR, such as intelligent glasses assistance, can reduce the error rate of classifying a large number of products in the warehouse (Remondino, 2020) and reduce the rate of defective products due to employee non- compliant technical operations (Fani et al., 2023). Also, in manufacturing assembly, AR technology is often used to intelligently project assistive technology guidance onto operational objects (Tao et al., 2019).

In essence, AR is an advanced human-computer interaction technology that centers on designing a new interface between "human and manufacturing resources". For example, an AR-based user interface with an eye-tracking device creates a more intuitive way to drive a motorized wheelchair (Chacon-Quesada & Demiris, 2019). In addition, an AR-based cyber-physical machine tool (CPMT) provides a more comprehensive interaction between workers and machines (C. Liu et al., 2021). It is clear that the level of digitalization in manufacturing which involves collecting product data and transforming it into a copy of a product in electronic devices for users to observe and study determines the effectiveness of AR applications.

2.2 3D printing technology

3D printing technology has achieved tremendous progress in the previous decades, yet it still faces challenges that cannot be disregarded, such as extrusion errors of materials, dimensional errors, and low printing efficiency (Chadha et al., 2022). These issues also suggest that 3D printing needs to implement and develop better technologies to solve existing problems. For example, deep learning techniques are now being applied to the process of quickly detecting and classifying printing errors to achieve the goal of optimal material availability (Paraskevoudis et al., 2020). Meanwhile, 3D printing's material utilization, printing efficiency, and production quality can be further improved using topology optimization techniques (Vantyghem et al., 2020). In addition, utilizing distributed control theory (pertaining to formulating decision-making guidelines for networks of interconnected parts, with the aim of accomplishing a common objective in situations that are characterized by uncertainty or dynamism (Marden & Shamma, 2015).) can have excellent results when scaling up collaborative 3D printing machines to improve manufacturing efficiency (Li et al., 2023), whether in a centralized organization (e.g., a company or production plant) or a decentralized structure (e.g., an individual studio or personal device). It is clear that although 3D printing equipment is much easier to use and manage than traditional manufacturing equipment (e.g., CNC machines) (Yau et al., 2015), it still requires specialized operators in this area. Therefore, it does not remove the threshold for non-technical personnel to penetrate the manufacturing stage, which reduces the technical accessibility of these 3D printing.

In conclusion, with the background of Industrial Revolution 4.0, 3D printing is playing an increasing role in efficient decision assistance, intelligent monitoring, process visualization, and rapid testing to help users solve many challenges in industrial manufacturing. However, there are few studies that consider these technologies as a collective whole, and there are no sufficient integration solutions to meet the individual requirements of the users. Therefore, this design project attempts to integrate AR and 3D printing in order to promote the learnability of the technologies and to propose a new software design scheme.

2.3 Conversational user interface with artificial intelligence technology

The initial purpose of conversational user interfaces (CUIs) was to imitate human conversations (Lee et al., 2019). In recent years, conversational user interfaces are becoming increasingly prevalent in everyday life and are anticipated to become even more ubiquitous in the future, as these interfaces are tailored for intricate interactions (Lister et al., 2020). Meanwhile, conversational AI technology is widely utilized in different domains such as artificial intelligence, marketing, psychology, computer science, and communication science and is closely related to machine learning, deep learning, and natural language processing (Song & Xiong, 2021). Based on that, like Siri, and Alexa, CUIs are used in everyday life to help in a variety of situations (McTear, 2021), for instance, helping to change diets (Casas et al., 2018) or guiding users in the financial sector (Scarpellini & Lim, 2020). Besides, Dominic et al. suggested that smart chatbots can be used as mentors or teachers (Dominic et al., 2020), specifically to provide information to students at the matriculation level (Page & Gehlbach, 2017). Therefore, the emergence of conversational agents has provided an opportunity to enhance the interaction between 3D printers and novice users, which can ultimately lead to a better user experience (S. Liu et al., 2021).

In general, the emergence of conversational agents not only enhances human interaction with technology across different domains but also presents a promising opportunity for novice users to effectively engage with 3D printers. Despite the technical accessibility and interface design challenges that novice users face when working with 3D printers, conversational agents like chatbots can offer tailored guidance and assistance to overcome these barriers, providing a more intuitive and user-friendly experience. As a result, the integration of conversational AI technology with 3D printing can not only improve user experience but also boost efficiency and productivity for users of all technical levels (Rymarczyk, 2020). With further research and development, conversational agents could play a significant role in unlocking the full potential of 3D printing technology (Dickel & Schrape, 2017) in various applications.

CHAPTER 3: SURVEY CONCLUSION

To gain a deeper understanding of the strengths and weaknesses of existing 3D printing software, a questionnaire was developed for this study, which received a total of 23 responses: 12 from individuals with a design background and 11 from those with an engineering background (as shown in Fig. 2). Furthermore, as illustrated in Fig. 3, among the respondents, 8.7% were competent, 34.8% were professional, 26.1% were advanced beginners, and 30.4% were novices. This data provides valuable insights into the current user base of 3D printing software and their proficiency levels, which can inform the development of more accessible and user-friendly software solutions.

- Competent: Fully capable of acquiring various knowledge about 3D printing and using various printers to meet various manufacturing needs without any obstacles.
- Professional: Ability to master most of the various applications on 3D printing and be proficient in using several printers to meet different manufacturing needs.
- Advanced beginners: The ability to perform simple 3D printing operations requires some assistance, such as viewing relevant learning tutorials.
- Novices: Unable to perform 3D printing operations autonomously at all, unless each step is performed according to the relevant tutorial.

Therefore, based on the user study, it is clear that a majority of individuals lack proficiency in using 3D printing software and printers. To better understand the strengths and weaknesses of existing 3D printing software, the study utilized seven of the most popular 3D printing software for testing. This approach allowed for the collection of valuable insights into each software's capabilities and limitations, thereby enriching the research material.

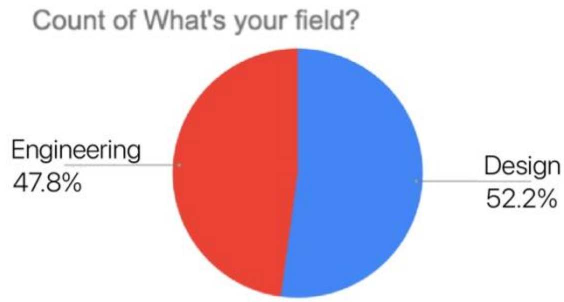


Figure 2. The background of the respondents

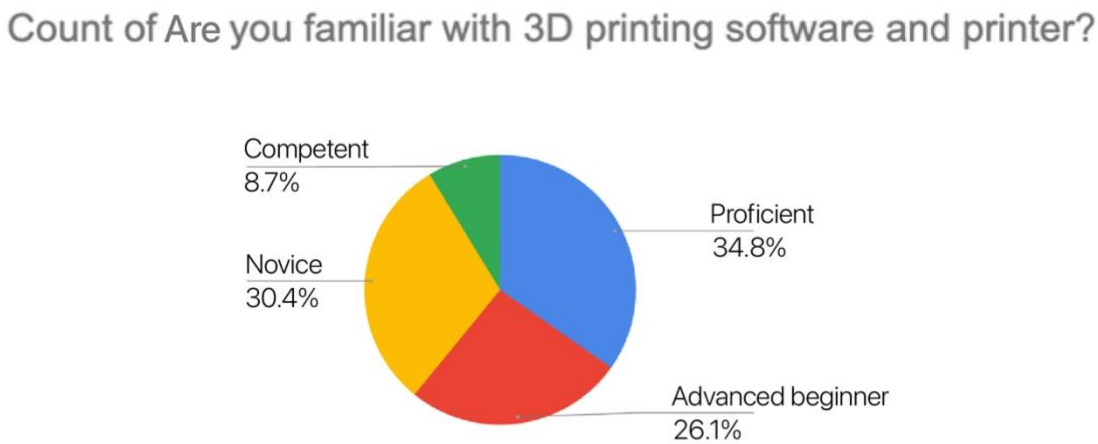


Figure 3. Respondents' technical proficiency with 3D printing software and printers

3.1 Questionnaire data

In the questionnaire, respondents were asked about the problems they encountered when they started using 3D printing. As shown in Fig. 4, the most common issue they identified was the need to follow a tutorial, which they felt was time-consuming. Other significant challenges included clogged printheads, complex parameter settings, difficulty in model arrangement, and running out of material during printing.

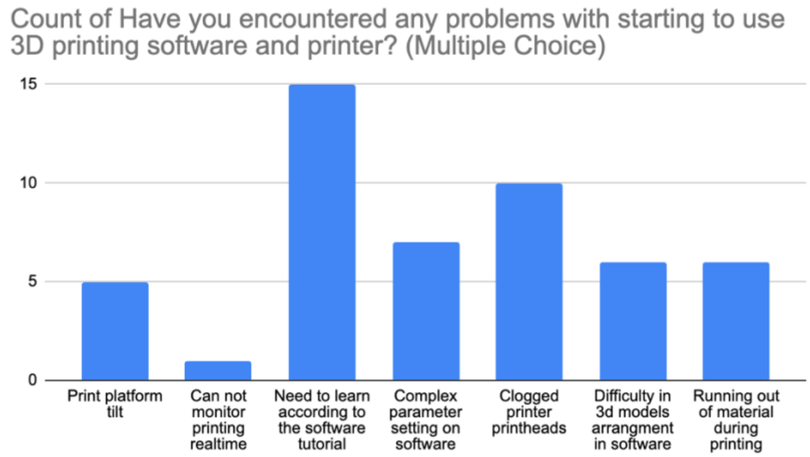


Figure 4. The problems encountered at the beginning of using 3D printing software and printer

In addition, the survey investigated the problems encountered in the use of different technical proficiencies. As shown in Fig. 5, users with high proficiency are more likely to experience printer failure problems, which may be due to their greater use and more complex printing requirements. On the other hand, users with low proficiency are more likely to experience problems learning how to use the software and printers, which underscores the need for more accessible and user-friendly interfaces and tutorials to support novice users in overcoming these challenges.

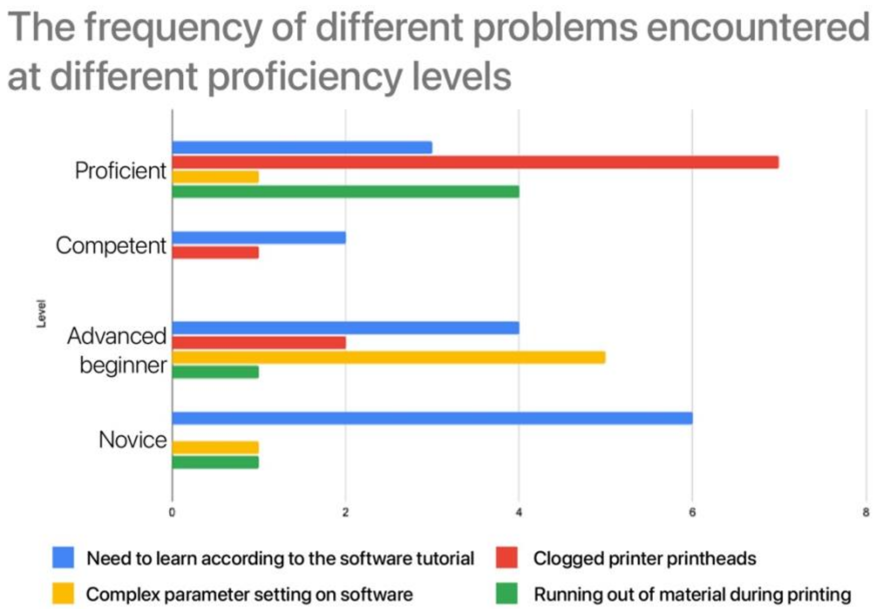


Figure 5. The problems encountered in the use of different technical proficiencies

The questionnaire also aimed to investigate the features that users expect from new 3D printing software (as shown in Fig. 6). The results indicated that the ability to monitor the printing process is the most highly anticipated feature. Users also expressed their interest in a clean and user-friendly software interface, intelligent presetting of print parameters, and the ability to easily find an available printer. These findings provide insights into the development of new 3D printing software that can better meet users' needs and expectations.

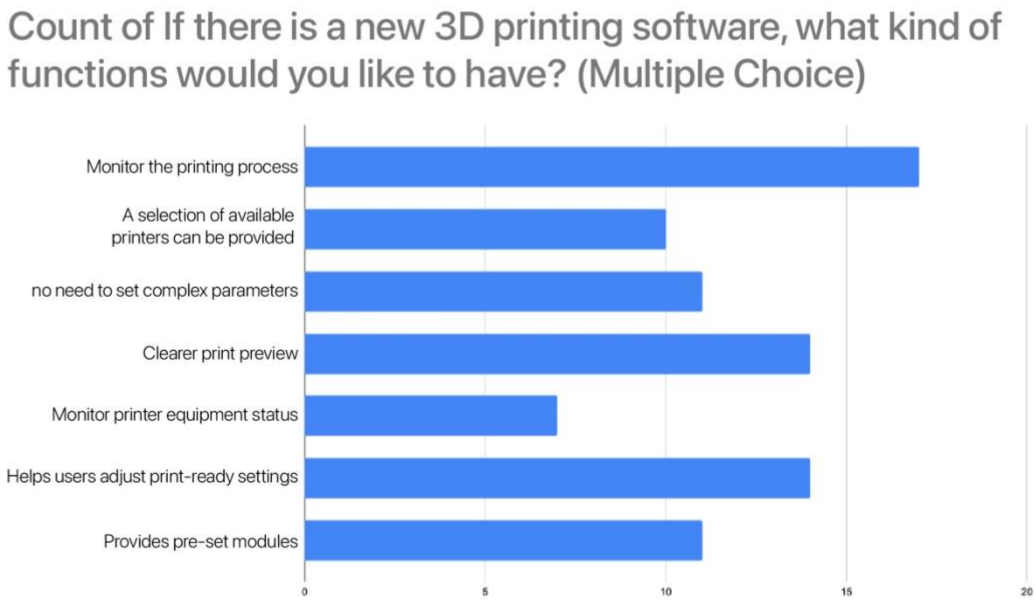


Figure 6. Users' expectations of the new software features

Meanwhile, as for the application of Augmented Reality, most users think that it will be useful (as shown in Fig. 7). Finally, there are some other suggestions interviewers left, such as "*Provide some tips towards different materials. For example, Abs is fatal, there might be some hints point out the warning*", "*If the material is going to run out during a print, it would be helpful to know how long it will take before it runs out, so you can plan accordingl*y.", "*Another major issue I have had with 3D printing is the amount of tolerance that should be given to a design because all machines print differently and add thickness to areas you may not have expected. Maybe something that could either automatically adjust your piece to account for the tolerance or tell you where the design will have an added tolerance*".

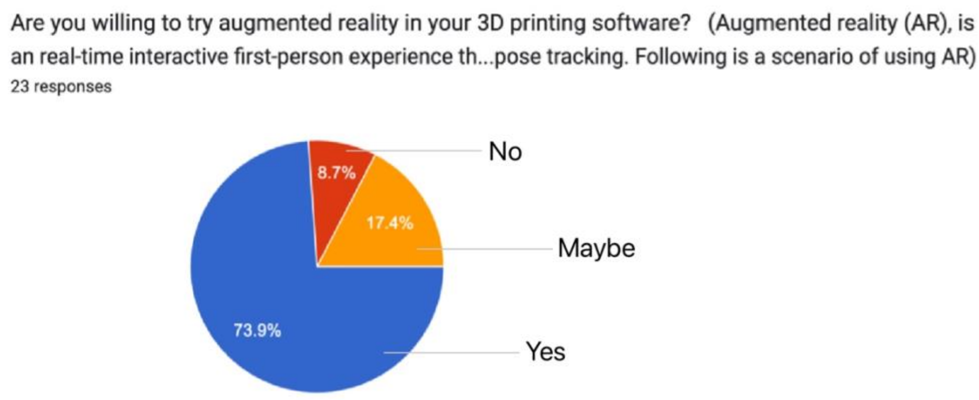


Figure 7. The expectation of AR function applied in 3D printing software

In general, the findings suggest that the main issues related to 3D printing software are the long learning curve, complex parameter settings, lack of control over the printing process, and other technical accessibility challenges. The questionnaire provides valuable insights and direction for future design studies aimed at improving user experience and addressing these challenges.

3.2 3D printing software tests

To gain a comprehensive understanding of the current landscape of 3D printing software, this study performed an in-depth analysis of several popular options. Both open-source and commercial software were included in the analysis, to provide a broad range of options for comparison. To gather user feedback, a total of 23 participants with varying levels of expertise in 3D printing software, predominantly at the novice level but also including some with professional experience, were recruited to use the software and provide their feedback. The decision to invite users with different levels of skill and experience was made to ensure a diverse range of perspectives and feedback and better understand the software's usability for users of different skill levels. This approach allowed for a more comprehensive evaluation of the software's user experience and helped identify areas of improvement.

The analysis of the software focused on both interface design and functionality. By documenting the strengths and weaknesses of each software, valuable insights were gained into areas for improvement and opportunities for future software design and development. Overall, this study aimed to contribute to the advancement of the new 3D printing software by identifying areas of improvement and promoting the development of more user-friendly and effective options.

3.2.1 3D printing software: Cura

Cura is a versatile and powerful 3D printing software that offers a wide range of features and functionalities. In addition to its ease with most 3D printers due to its clear and simple interface as well as broad compatibility with various printer models and brands, Cura also has a plugin system that allows users to extend its capabilities with a variety of useful plugins. The software also comes with a vast library of print profiles that can be easily downloaded and imported, making it easier for users to get started with their 3D printing projects quickly. One of the most significant advantages of Cura is its intuitive interface management. For example, when users log in to the "Basic" mode, they can quickly reconfigure the most basic printer quality settings. However, when they need more precise control over print settings, they can easily switch to "Advanced," "Expert," or "All" modes to access more settings (as shown in Fig.8). With more than 400 settings to choose from in these modes, users can adjust them as needed to achieve the best results.

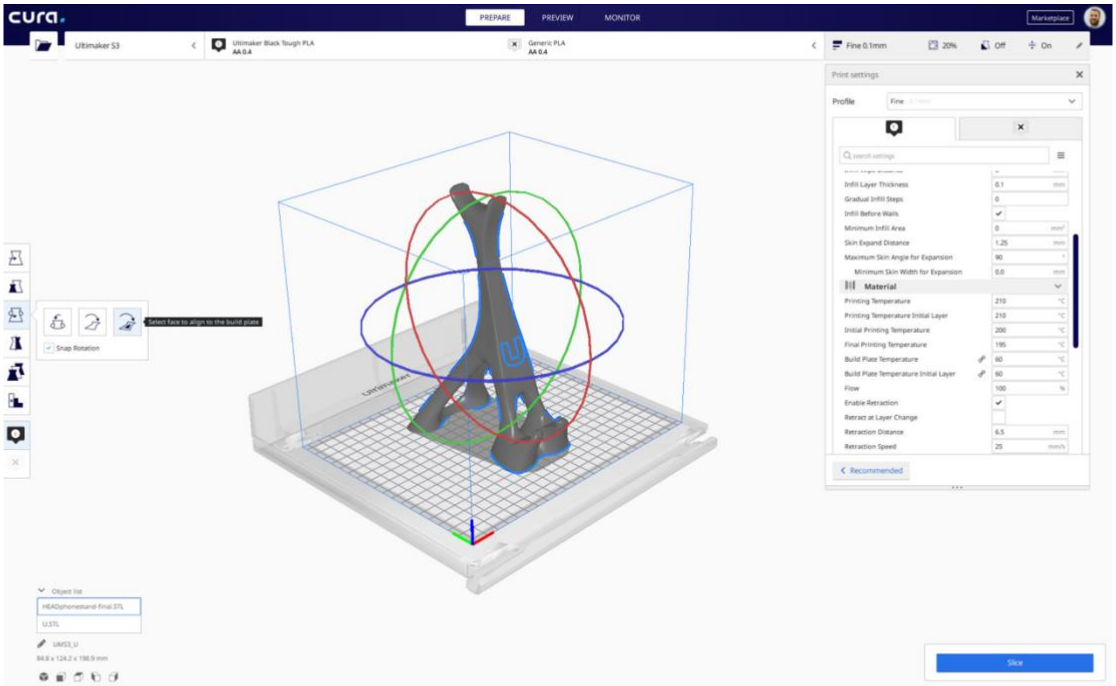


Figure 8. Cura interface (*Ultimaker Cura 4.3: Available Now*, n.d.)

Moreover, Cura has a feature called "Slice Settings Preview (the Computer-Aided Design (CAD) models are separated into distinct layers, and a path for the printing head movement must be planned for each layer to deposit the necessary materials (McPherson & Zhou, 2018).)," which allows users to preview the effect of changing different slicing settings on their 3D prints. This feature helps users to fine-tune their settings to get the best possible results before printing. Additionally, Cura's "Mesh Tools" feature allows users to make various modifications to their 3D models before printing, such as scaling, rotating, and translating.

Overall, Cura is an excellent choice for both beginners and experienced 3D printing enthusiasts, as it offers a wide range of functionalities and is easy to use with most 3D printers. Its extensive library of print profiles and plugins, combined with its intuitive interface management, make it an ideal software for users looking to achieve high-quality 3D prints.

3.2.2 3D printing software: PrusaSlicer

PrusaSlicer is another popular slicing software (as shown in Fig. 9) that has gained a lot of popularity due to its large number of adjustable settings and some handy features not found in other software. For example, the software offers handy presets for some common materials and features customizable support structures, multi-material supports as well as smooth variable layer heights. another advantage of PrusaSlicer is that it can be used to slice models for both FDM and resin printers, making it a versatile option for many 3D printing enthusiasts.

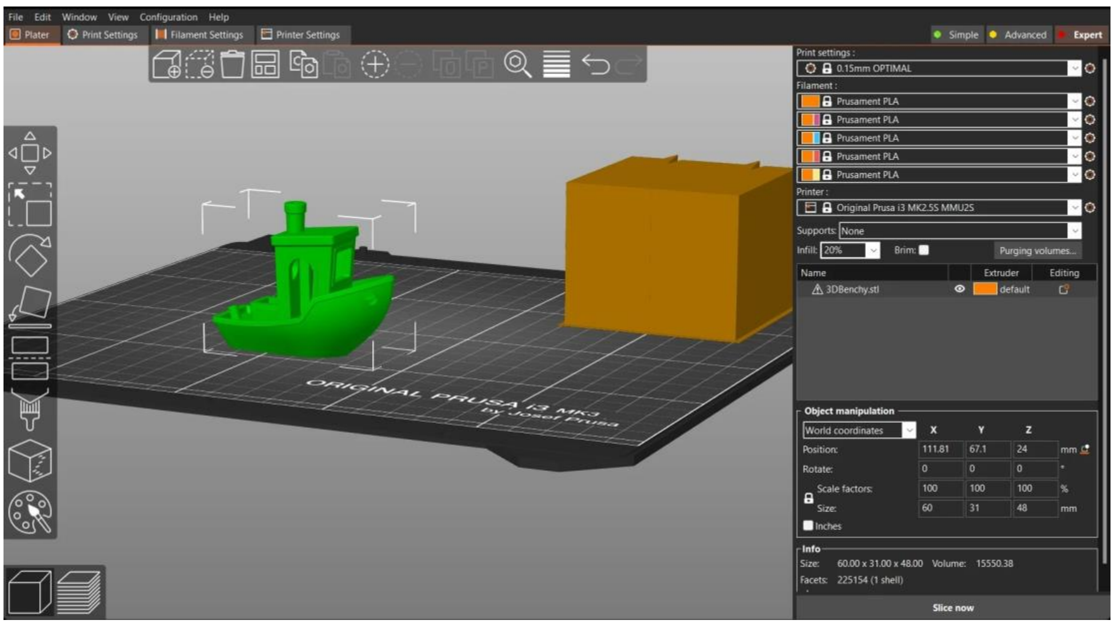


Figure 9. PrusaSlicer interface (*PrusaSlicer: All You Need to Know | All3DP*, n.d.)

In addition, PrusaSlicer offers a variety of modes that allow users to edit settings to suit their skill level, with the expert mode opening up a huge list of possibilities for more experienced users to customize. However, even simple profiles perform well in PrusaSlicer, and it is equally easy to adjust or import custom settings. The software's interface is intuitive and user-friendly, allowing users to quickly find and adjust the desired settings.

On the whole, PrusaSlicer is a powerful and versatile slicing software that offers many features and customizations for beginners and experienced users alike. Its intuitive interface and easy-to-use features make it an excellent choice for anyone who wants to get the best out of their 3D printing projects.

3.2.3 3D printing software: ChiTuBox Basic

ChiTuBox Basic (as shown in Fig. 10) is a software designed to specifically slice 3D models for LCD-based resin 3D printers, commonly known as Masked Stereolithography or MSLA printers. The software provides users with extensive control over the printer's curing settings and motion behavior, as well as a wide selection of popular printer models to choose from. One crucial aspect of resin print preparation is the orientation of the model and holder configuration, both of which are covered by ChiTuBox Basic. However, the software's model orientation is somewhat basic, lacking an automatic orientation feature. Nonetheless, the automatic support generation feature is robust and provides satisfactory results in many cases. Although the software may require further customization to better support the user's prints, the customization options are user-friendly and intuitive.

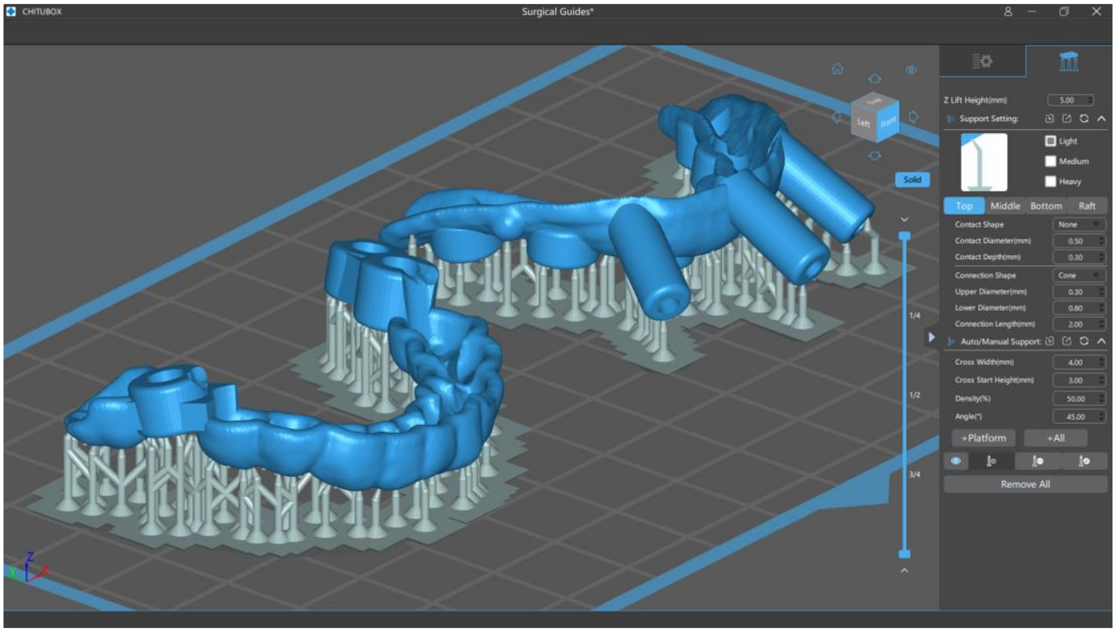


Figure 10. ChiTuBox Basic interface (*CHITUBOX* / *All-in-One SLA/DLP/LCD Slicer* / *3D Printing Preprocessing Software*, n.d.)

3.2.4 3D printing software: ideaMaker

Raise3D's slicing software, ideaMaker (as shown in Fig. 11), is a powerful tool that is primarily designed to work with the company's 3D printers but can be used with other third-party printers as well. While the user interface and workflow may seem a bit more complex compared to Cura and PrusaSlicer, it offers an array of advanced features that are useful for experienced 3D printing enthusiasts.

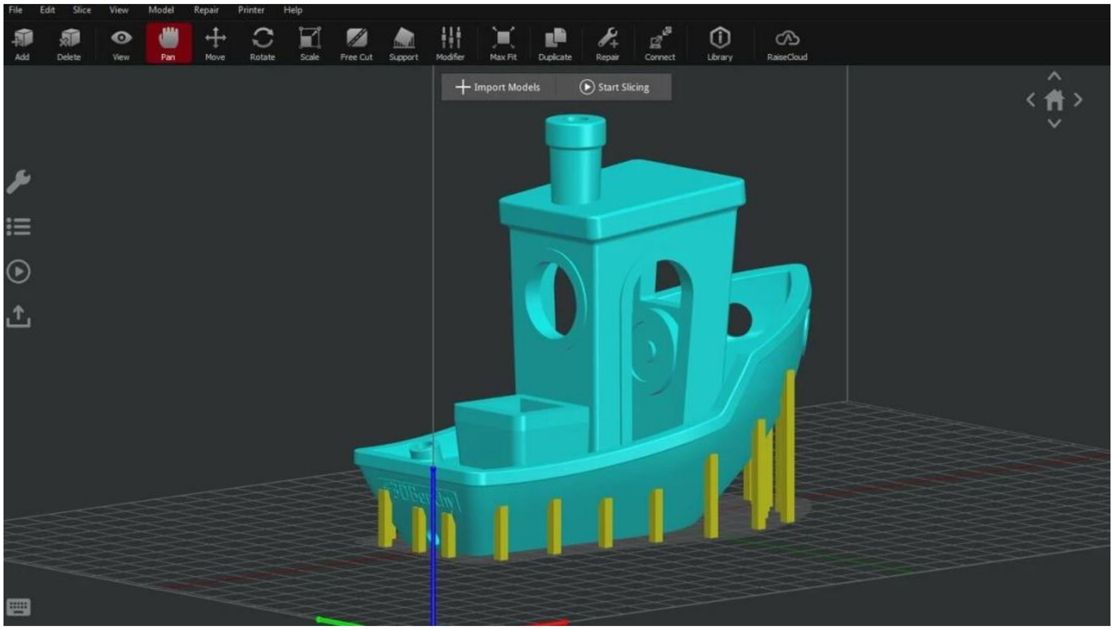


Figure 11. ideaMaker interface (*IdeaMaker (Slicer): How to Get Started | All3DP*, n.d.)

One of the key strengths of ideaMaker is its ability to customize print settings for each layer, allowing users to easily adjust depth settings and print modifiers. Additionally, the software has the ability to wrap textures around prints, which can be useful for branding or customizing parts. The software also connects to Raise3D's cloud services, which provides access to hundreds of community and Raise3D-created printer and material profiles for faster and more efficient printing. This feature also allows users to create their own library of preferred settings and profiles.

ideaMaker offers several advanced features, including customizable support structures, optimized model stitching for large prints, and mesh repair tools. These features give the software versatility and make it an ideal choice for users who need more advanced slicing capabilities.

In summary, while the ideaMaker user interface may be a bit more complex, it offers a wealth of advanced features that make it a powerful tool for experienced 3D printing enthusiasts who are looking to fine-tune their printing settings for optimal results.

3.2.5 3D printing software: IceSL

IceSL is an exceptional 3D printing software (as shown in Fig. 12) that combines the features of a 3D modeling tool and a slicer, making it a one-stop shop for all your 3D printing needs. The software's intuitive interface and user-friendly workflow make it easy for both novice and experienced users to create and prepare 3D models for printing.

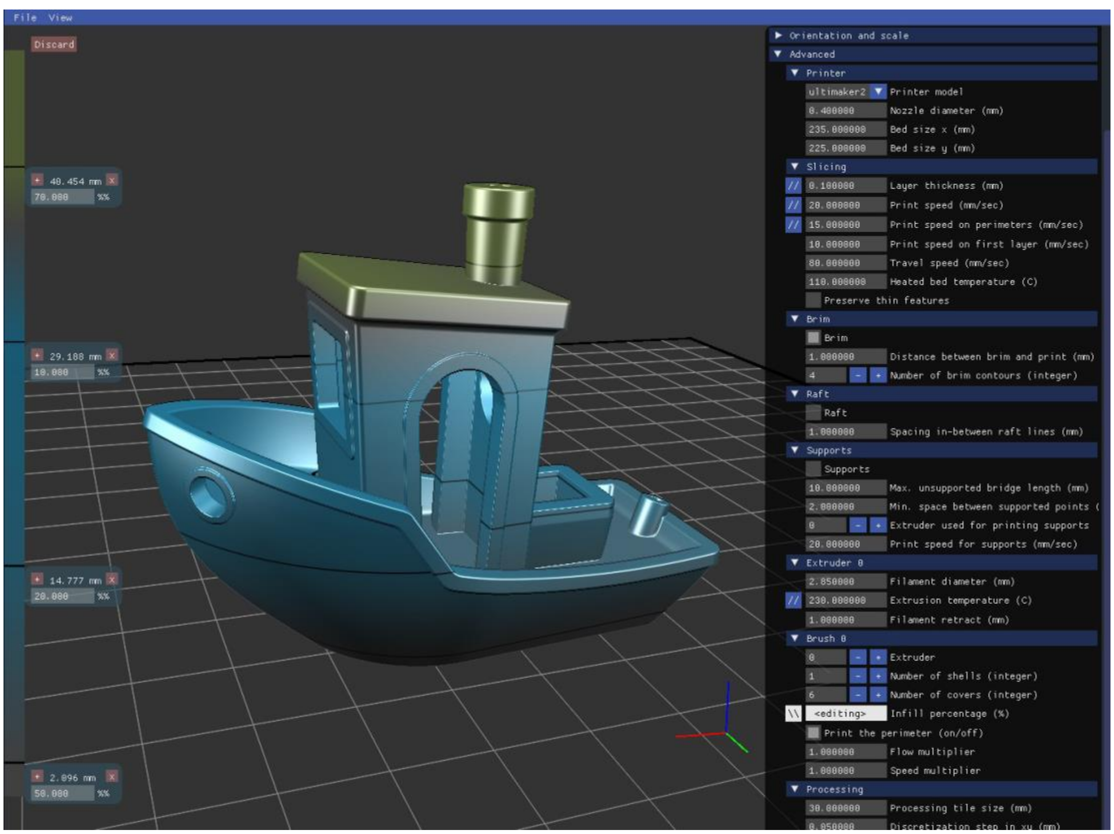


Figure 12. IceSL interface (*Features*, n.d.)

One of the most significant advantages of IceSL over other slicing software is its powerful Lua scripting engine. This scripting engine allows users to customize their 3D models and control the slicing process with an unprecedented level of precision. The software also offers a range of slicing settings, with beginner-friendly options for quick and easy slicing and advanced settings for more experienced users. In addition, IceSL's ability to specify different values for print settings at certain layer heights enables smooth transitions from dense to light fills and fine to coarse layer heights, among others. This feature helps users achieve high-quality prints with minimal defects and visible layer lines.

Moreover, the IceSL team has been working on the software for years, refining and perfecting it to provide the best possible user experience. The result is a comprehensive 3D printing software that is fast, reliable, and versatile, with a range of "nifty tricks" up its sleeve.

In conclusion, IceSL is an excellent choice for anyone looking for powerful and versatile 3D printing software that offers a range of features for both 3D modeling and slicing.

3.2.6 3D printing software: OctoPrint

OctoPrint is a web-based "pure" 3D printer host that allows users to have full control over their 3D printer and print jobs (as shown in Fig. 13). Created by Gina Häußge, OctoPrint is a powerful tool that has quickly become a go-to for many 3D printing enthusiasts. It is designed to be used with a Wi-Fi-enabled device, such as a Raspberry Pi, connected to the user's own printer, allowing the user to dial in and control the machine remotely via OctoPrint's web interface.

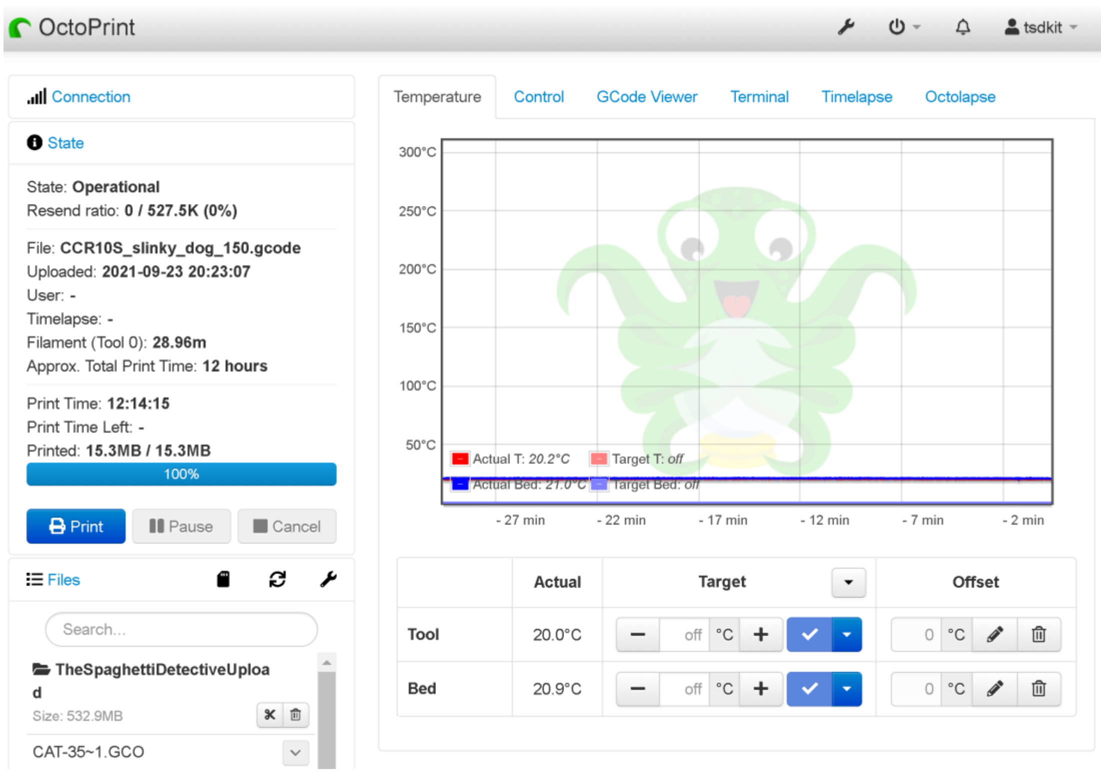


Figure 13. OctoPrint interface (*How To Setup OctoPrint the Easy Way | Obico Knowledge Base*, n.d.)

One of the biggest advantages of OctoPrint is its ability to accept G-code from almost any slicing software, which makes it incredibly versatile. The software also includes a gCodeVisualizer that allows users to preview files before and during 3D printing, giving them the opportunity to catch any issues before they become a problem. Alternatively, users can slice STL files directly in OctoPrint, using it as an all-in-one print-ready package.

OctoPrint not only provides users with a number of tools to remotely control the printing process but also offers a variety of ways to keep track of ongoing print jobs. Users can set OctoPrint to send push notifications or alerts through various messaging applications, which is incredibly helpful for those who want to keep an eye on their printer's progress while they are away.

Another great feature of OctoPrint is its extensive library of plugins, providing easy access to innovative plugins created by a tight-knit community. The plugins can be used to add additional functionality to the software, such as a time-lapse camera or a filament sensor. And, if users can't find what they're looking for, they can create their own plugins with OctoPrint's flexible API.

All in all, OctoPrint is a highly versatile and powerful software that is great for anyone who wants to have full control over their 3D printer and print jobs. While it may take a bit of setup to get going, the features and benefits are well worth the effort.

3.2.7 3D printing software: Fusion 360

Fusion 360 is a game-changer in the field of 3D printing software (as shown in Fig. 14). As a professional CAD program developed by Autodesk, it stands out from other solid 3D design tools thanks to its comprehensive capabilities and ability to cover the entire process of planning, testing, and executing 3D designs. With a powerful set of parametric tools, Fusion 360 allows users to easily create and modify intricate designs while ensuring their accuracy and efficiency.

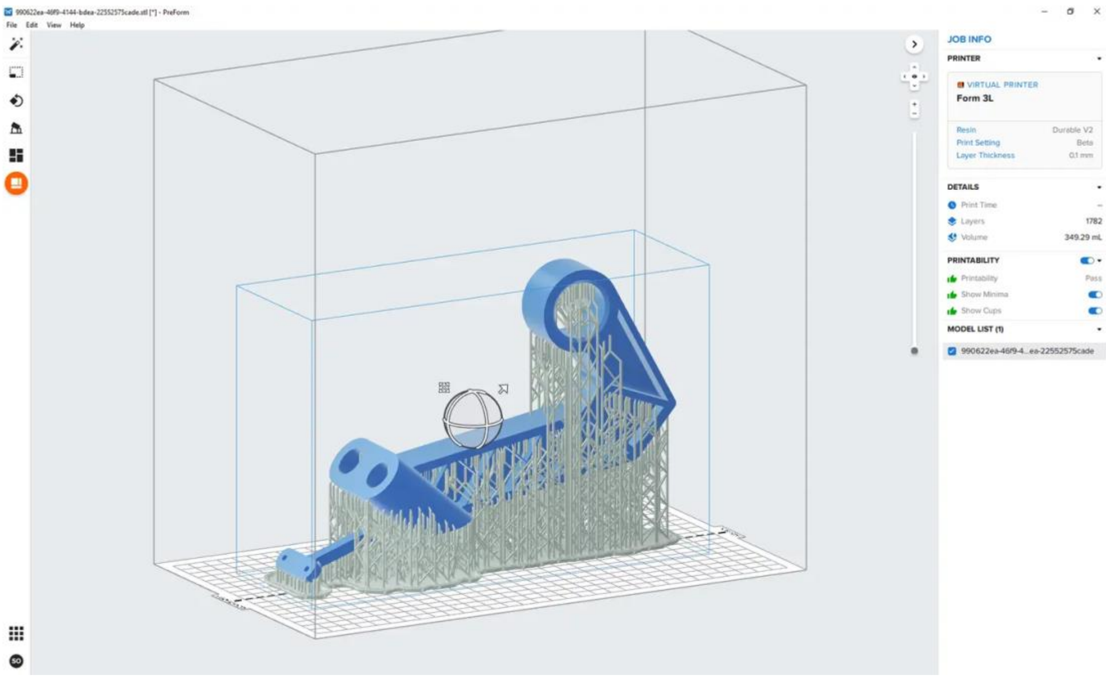


Figure 14. Fusion 360 for 3D printing interface (*Fusion 360 3D Printing Tutorial: Tips to Prepare Your Design for 3D Printing | Formlabs*, n.d.)

One of the key features of Fusion 360 is its analytical meshing tools, which enable users to simulate the structure of designed parts and the stresses they will face when manufactured and put into use. This feature is particularly useful in industrial design, where accuracy and durability are essential. With Fusion 360, designers can create and test their designs before they are even printed, saving time and resources in the production process.

Another standout feature of Fusion 360 is its sophisticated collaboration capabilities. With cloud-based file sharing, version control, and the ability to import and export common CAD file types, Fusion 360 makes it easy for teams to work together on projects. And, with its seamless integration with 3D printers, users can easily print their designs directly from the software.

Overall, Fusion 360 is an excellent choice for professionals and hobbyists alike who are looking for comprehensive and powerful 3D printing software. With its advanced parametric tools, analytical meshing tools, and collaboration capabilities, it sets the standard for CAD software in the 3D printing industry.

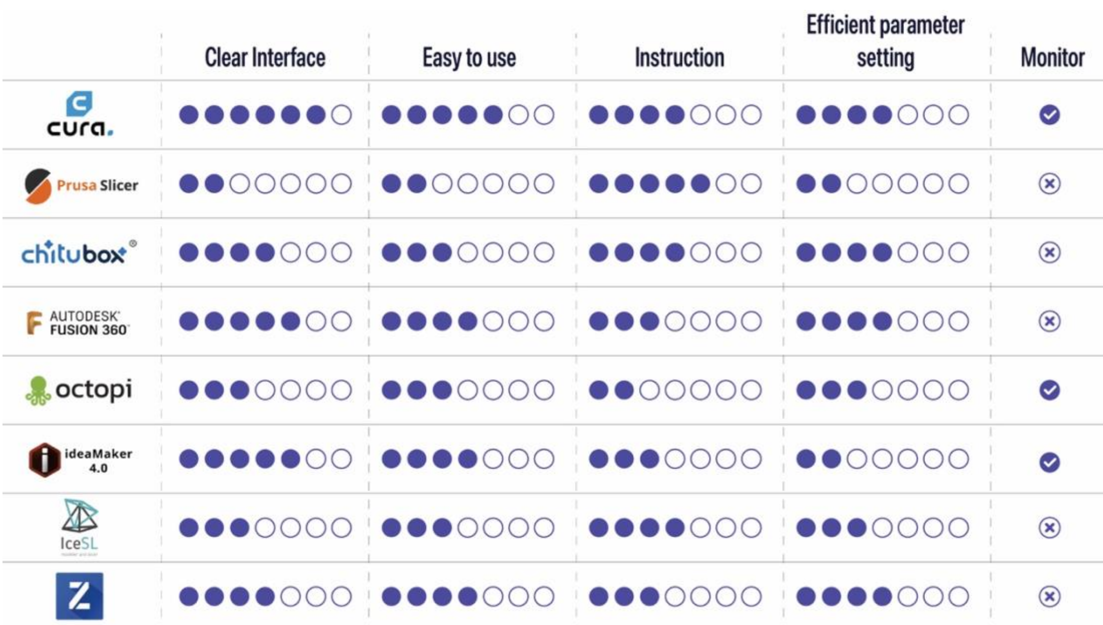


Figure 15. Traditional software analysis

The user survey depicted in Fig. 15 has been an essential tool in understanding the user experience and identifying the key features of various 3D printing software. This survey has been instrumental in gaining insights into how novice and advanced users interact with different software and what their expectations are from such software. The results of the survey revealed that Cura is currently the most widely used and highly rated software by users. This finding is important for designers to consider when developing new 3D printing software.

Despite the popularity of certain software, the survey also revealed significant shortcomings in terms of technical accessibility and interface design across the board. These shortcomings are especially prevalent for novice users who lack technical experience in using 3D printing software.

For such users, these issues can be a significant barrier to entry, hindering their ability to fully utilize the technology.

It is, therefore, imperative to address these shortcomings and design software that is more user-friendly and accessible for users of all technical levels. This includes improving the overall interface design, simplifying tools, and incorporating more intuitive workflows. A user-friendly design can increase user adoption and reduce support requests and errors (Ngai et al., 2007).

Indeed, there is always room for improvement in 3D printing software, and addressing these issues can make a significant impact on the user experience. For example, providing clear and understandable guidance on material selection and parameter settings can help users avoid errors and achieve better results. Similarly, improving the interface to display real-time printer status and location can help users monitor their prints more effectively and avoid unnecessary downtime. Additionally, integrating tools for automatic calibration, error detection, and troubleshooting can help users overcome technical challenges and achieve more consistent and reliable results. Ultimately, by continuously learning from user feedback and improving the design of 3D printing software, it can help make this exciting technology more accessible, user-friendly, and beneficial for a wider range of users.

CHAPTER 4: DEFINING THE TARGET USER FOR 3D PRINTING SOFTWARE

To design 3D printing software that effectively meets users' needs and expectations, it is crucial to have a clear understanding of the target user profile. Novice users or those who are unfamiliar with 3D software may have different needs and preferences compared to advanced users. Novice users, for instance, may require a more user-friendly interface and simplified tools to help them get started with 3D printing due to they are often less familiar with the technology, whereas advanced users may require more sophisticated features and customization options. By defining the target user profile, this design project can gain a better understanding of the user's perspective and design software that caters to their needs, resulting in increased user satisfaction and adoption rates, as well as reduced user errors and support requests.

Figure 16. Target user persona

A graphic designer interested in 3D printing technology is depicted in Fig. 16. He is passionate about exploring new technologies and pushing the boundaries of what is possible in design. However, he also feels a great deal of distress and frustration due to his lack of technical experience with 3D printing. This is a common problem that many designers are currently facing.

Designers like him are typically familiar with 2D design software, such as Adobe Illustrator or Photoshop, but may lack experience with 3D modeling software. They may be interested in 3D printing for a variety of reasons, including prototyping, product design, and creating custom designs. However, they may feel overwhelmed by the technical details involved in 3D printing, such as material selection, printer settings, and file formats.

It is essential to consider the needs and preferences of novice users like this graphic designer when designing 3D printing software. By taking into account their lack of technical expertise and desire for a user-friendly interface, designers can create software that is accessible and easy to use, even for those without experience with 3D printing. This can help to reduce user errors, increase adoption rates, and improve overall user satisfaction.

CHAPTER 5: SOFTWARE WORKFLOW LOGIC DESIGN

Software workflow logic is an important aspect of software design that can greatly impact user experience and efficiency. Traditionally, software workflows have been based on linear, step-by-step processes, where users must follow a specific sequence of actions to achieve their desired outcome. While this approach can be effective for certain types of software, it can also be limiting and frustrating for users who may have different needs or prefer a more flexible approach.

To enhance the software workflow logic, it is essential to analyze the traditional workflow thoroughly and identify areas where it can be improved or streamlined. This analysis can involve the identification of bottlenecks, redundant steps, and areas where users may encounter difficulties or confusion. To address these issues, the new software incorporates non-linear elements into the workflow (as shown in Fig. 17), such as branching paths or decision points, that allow users to take different routes to achieve their goals. Additionally, the new software also considers leveraging automation or intelligent algorithms to anticipate user needs and offer suggestions or solutions before they are even requested.

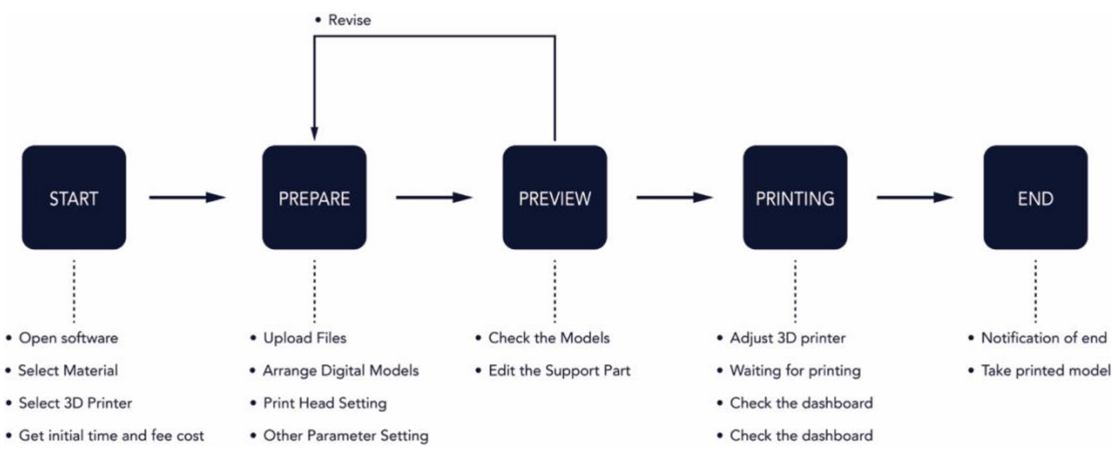


Figure 17. New software workflow

All in all, the primary goal of improving software workflow logic is to foster an intuitive, user-friendly experience that boosts efficiency and productivity. To evaluate the success of the primary goal, user surveys can be conducted after the software is completed. These surveys can provide valuable insights into user satisfaction and identify areas for improvement, allowing for further optimization of the software. Additionally, metrics such as completion rates and error rates can also be used to measure the effectiveness of the solution. By thoroughly comprehending the needs and preferences of the target users, the new software can create a logical workflow that aligns with their requirements and expectations. This can be achieved by integrating features such as branching paths or decision points, and by automating processes and utilizing intelligent algorithms to offer users suggestions or solutions before they even request them. By incorporating such features, the new software can provide users with the flexibility and customization options they need to achieve success in their 3D printing endeavors.

CHAPTER 6: SOFTWARE MOODBOARD DESIGN

A mood board is a tool used in the design process to establish a visual direction for a project. It is a collection of images, colors, textures, typography, and other design elements that represent the desired style and mood of the final product. In the case of software UI design, a mood board can help establish the aesthetic and functional direction of the user interface based on the target users and the intended style for the technology. Thus, to ensure that the software user interface is both aesthetically pleasing and functional, a mood board is utilized to establish the design direction for the project. The mood board will be based on the target users (like 3D printing enthusiasts) and the intended style for the technology. By incorporating design elements that are appealing and user-friendly to beginners, the process of 3D printing becomes more accessible and enjoyable for a wider range of users (as shown in Fig. 18).

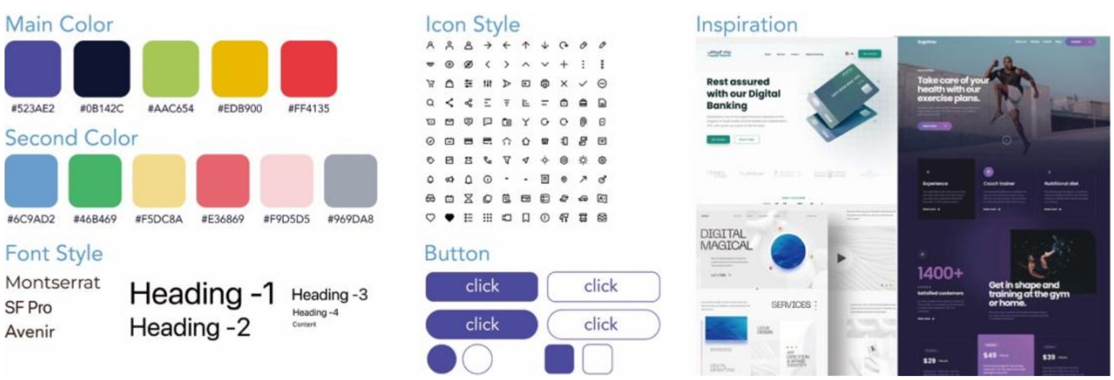


Figure 18. Software mood board

To enhance the user experience of the software UI design, careful consideration of color selection is important. The primary color group should have high saturation and strong contrast to improve the software interface's recognizability, particularly in comparison to traditional industrial software. High contrast colors also aid in distinguishing different functional blocks, increasing the software's usability. Additionally, utilizing high saturation colors can provide a dynamic look to the interface, which contributes to conveying the software's technical accessibility. By applying these design principles, the resulting software will have an attractive and user-friendly interface, effectively meeting the needs and preferences of the target user group. Meanwhile, the choice of fonts plays a crucial role in determining the technology-oriented character of the interface. With a focus on enhancing the sense of technology, the software in question adopts a sans-serif font style with rounded corners, enabling better legibility of the text and conveying a friendly, accessible vibe. In a similar vein, the icons and buttons are designed with simplicity and user-friendliness in mind, further reinforcing the overall sense of technical sophistication.

CHAPTER 7: SOFTWARE IDEATION AND PROTOTYPING DESIGN

To explore and enhance the technical accessibility of 3D printing software, this project adopts a human-centered design approach and research through design methodology. Based on the current level of scientific and technological development, the software design introduces an initial concept of using an intelligent conversational assistant, which has been improved and implemented in this study. In addition, the software prototype has been designed to lay the foundation for the software's operation logic, appearance, and functionality in the future.

7.1 AI 3D print assistant

It was determined during the design stage of 3D PrintAssist that a chat-based interface would be more suitable for the software's conversational user interface (CUI) instead of a voice-based interface based on various factors, such as user preferences (users basically use keyboard and mouse operations when using software) and usability research (computers have the highest ability to understand the text). This decision was based on the requirement to handle visual data, including 3D models, images, and videos, during software usage.

When a user uses 3D PrintAssist, the chatbot will start by introducing itself and providing a brief overview of its capabilities, followed by a prompt such as "What can I do for you?" The chatbot then enters an idle mode and awaits user input. At this point, the conversation structure is open-ended, and users are required to type in their requests or queries. The current implementation features four distinct conversation branches: (1) hardware information intent, (2) workflow information tutorial, (3) software information intent, and (4) print intent, as depicted in Fig. 19.

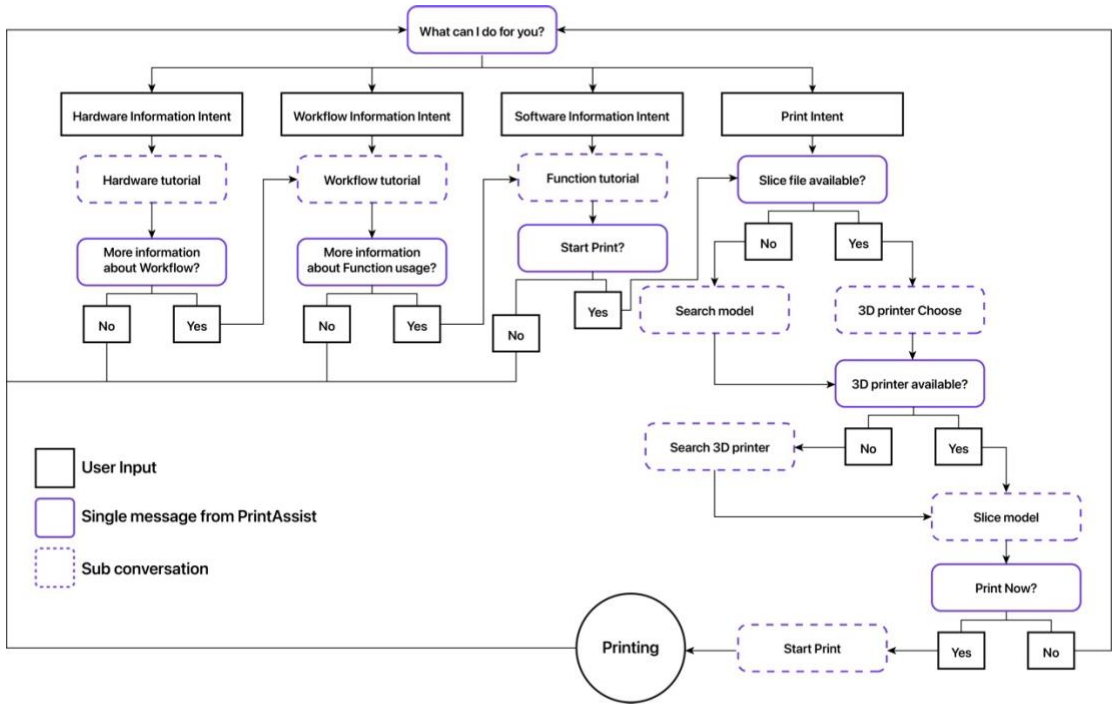


Figure 19. 3D PrintAssist structure

7.2 Prototyping design

Prototyping design is essential in the software development process as it allows developers to visualize and test their ideas before fully implementing them. By creating a prototype, developers can quickly identify potential design flaws and usability issues that may not have been apparent in the initial design phase. It also enables developers to gather feedback from potential users and stakeholders, which can be used to refine and improve the final product. In the case of 3D printing software, prototyping design can help ensure that the software's operation logic, appearance, and functionality meet the user's needs and expectations (Wilson & Rosenberg, 1988).

7.2.1 Dashboard page prototype

The term "dashboard prototype" refers to an initial or sample version of a dashboard, which is a tool for managing information by displaying important data points and indicators of current printing tasks in an easily understandable format, facilitating user tracking and management of such tasks. Fig. 20 illustrates that the central component of the interface is the real-time monitoring of printing tasks, with key information about printing tasks located on the right. Additionally, users can view several ongoing tasks and generate new printing tasks. Specifically, it emphasizes the importance of real-time monitoring of printing tasks and the location of key information related to these tasks. Designing these features illustrates the benefits that users, especially novice users, can derive from an interface that effectively presents relevant information and supports efficient task management.

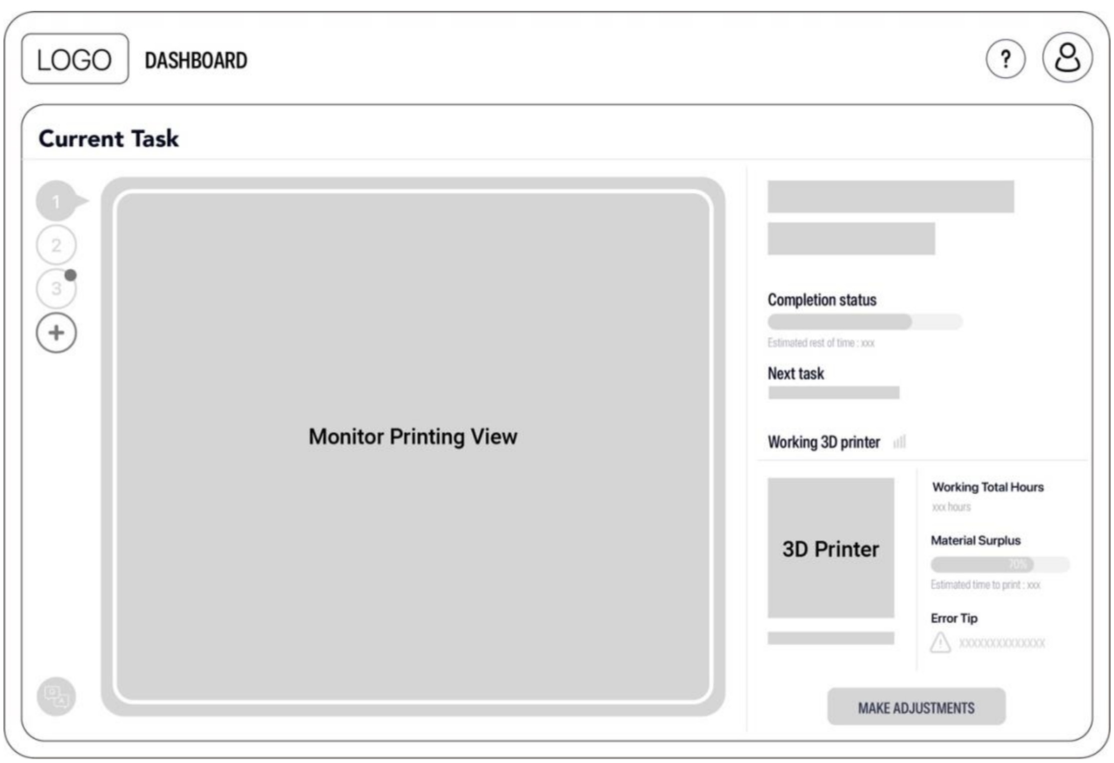


Figure 20. Dashboard prototype

Overall, the dashboard prototype is a simulation of the dashboard's design and functionality, enabling testing and refinement of its characteristics and layout before the final version is developed. In specific, by testing the prototype with target users, data can be gathered on its effectiveness, and necessary adjustments can be made to enhance the user experience. Besides, the design and layout of the dashboard will be refined based on user feedback to ensure that it meets the needs of its intended users.

7.2.2 Dashboard page-Choosing 3D printer prototype

The Dashboard page - Choose a 3D Printer prototype is a preliminary design or model of a dashboard that assists users in selecting the most suitable 3D printer for their requirements, as novice users often struggle to choose a suitable 3D printer due to a lack of relevant knowledge and experience in the field (Tully & Meloni, 2020). This prototype allows users to filter through different 3D printers in an easy-to-understand and intuitive manner, enabling them to compare and make the best choice based on their specific needs, for example, help novice users filter and compare different 3D printers in an easy-to-understand and intuitive manner. The interface (as shown in Fig. 21) divides the printer range on the left based on the user's actual requirements, such as the price, material, and printer size, while the right side helps users estimate the approximate size of their electronic model, which can be particularly helpful for novice users who may not be familiar with specific model sizes.

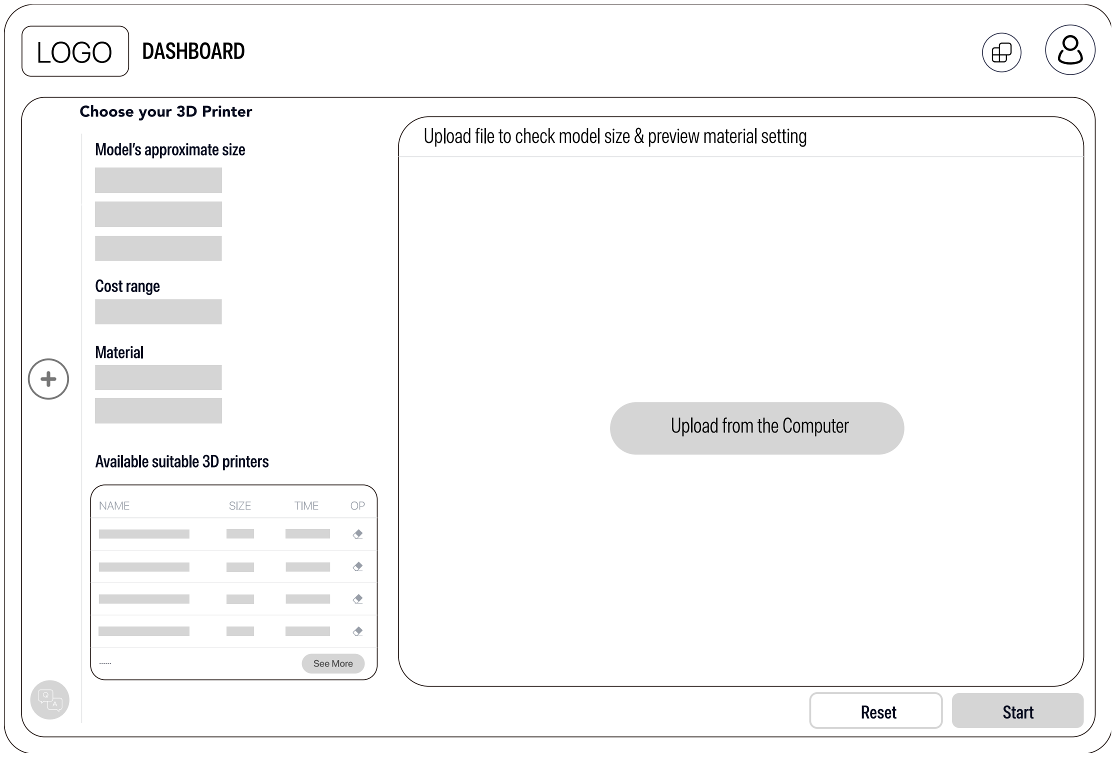


Figure 21. Dashboard-Choosing 3D printer prototype

7.2.3 Prepare page prototype

A prototype of a preparation page is a preliminary version or model of an interface that assists users in preparing their 3D models for printing. The prototype provides users with the capability to upload, edit, and prepare 3D models for printing. Figure 22 displays the primary functional area, including file upload, model editing, and printer settings, on the left side of the preparation page prototype. What's more, there is an AI-assisted for help user to save time and solve some parameter setting problems. However, while an AI-assisted setting can be helpful in improving the quality and efficiency of the 3D printing process, manual adjustments are still necessary in many cases. For example, AI may not always provide the optimal setting for certain materials or models, and manual adjustments may be required to achieve the desired results (Zappone et al., 2019). Additionally, some users may prefer to have full control over the printing process and may want to manually adjust the settings to achieve their specific design objectives (Yap et al., 2016). Therefore, the right side of the interface also keeps detailed adjustments to the uploaded model, such as moving, rotating, and mirroring. Besides, users at varying levels of expertise may need to make detailed adjustments to their uploaded models based on their specific requirements. For instance, novice users may require detailed adjustments to refine and improve their designs, while professional users may need to make precise adjustments to achieve a specific outcome or to address complex design challenges. Therefore, a combination of AI-assisted and manual adjustments can provide users with the flexibility and control needed to achieve their desired outcomes.

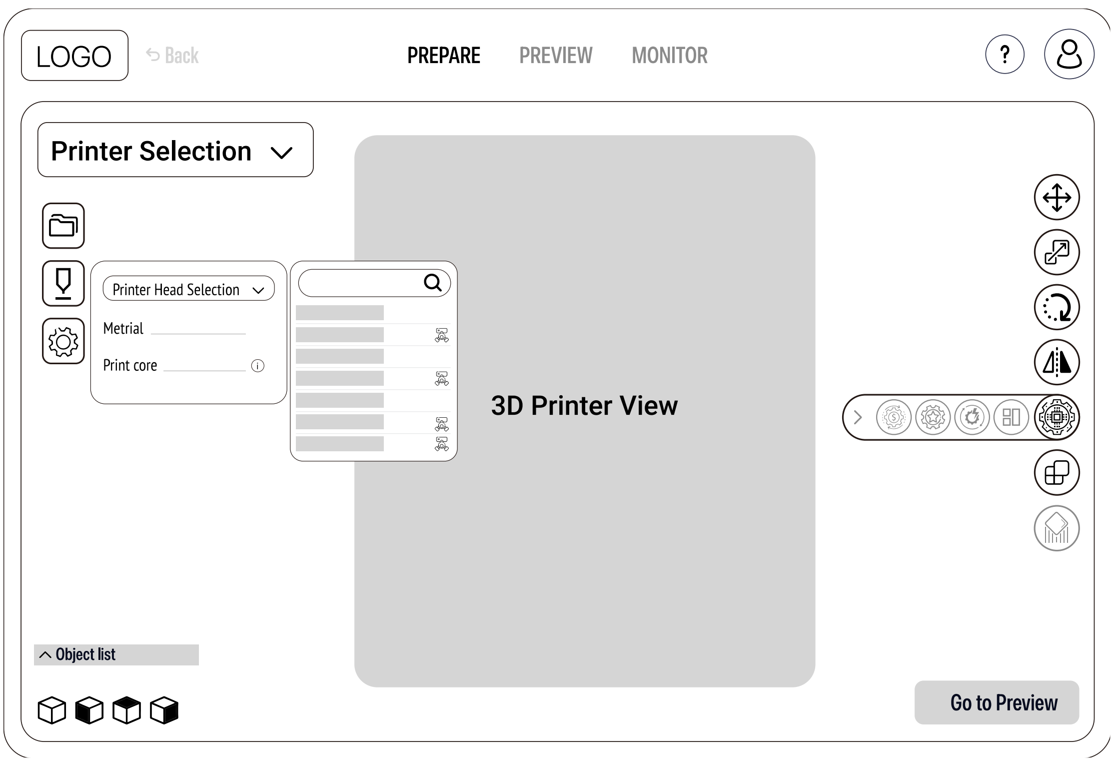


Figure 22. Prepare page prototype

7.2.4 Preview page prototype

A preview page prototype is an initial version or design of an interface that permits users to preview their 3D models before initiating the printing process. The prototype of the preview page provides users with a clear and comprehensive view of the 3D model and its positioning on the print bed. This feature is particularly important because it helps users, including novice users, to identify any potential errors or areas for improvement before printing. Novice users may focus on checking for any design issues or errors that could negatively impact the quality of the print, such as uneven surfaces or structural weaknesses. Additionally, they may use this view to adjust the positioning of their model on the print bed to ensure that it will be printed correctly. As shown in Fig. 23, the software enables users to make final adjustments to the size and position of the model to ensure it is appropriately placed on the print bed and display the printing time and cost in a timely. This step is crucial in the 3D printing process, as it enables users to ensure the quality, like the object's surface finish, density, and the results from different printing accuracy chosen for their final product.

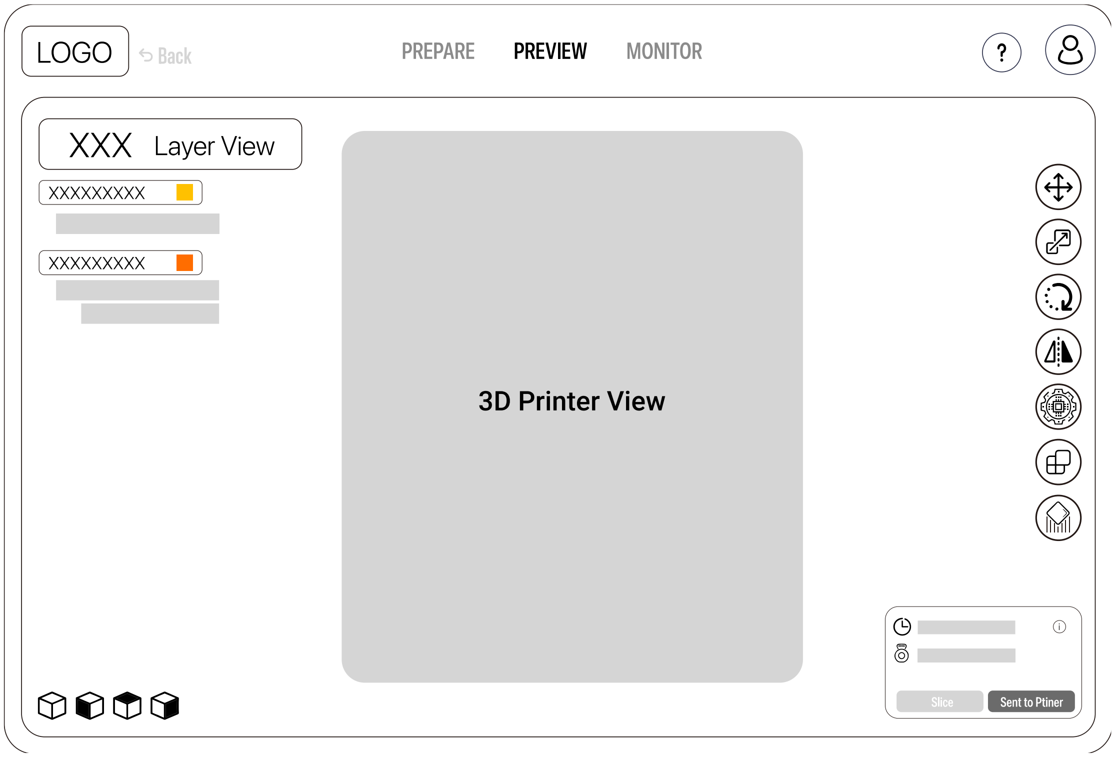


Figure 23. Preview page prototype

7.2.5 Monitor page prototype

A monitor page prototype is a preliminary version or model of an interface that helps users monitor the progress of their 3D printing tasks. This prototype provides users with real-time updates on the status of their print job, including details such as time remaining, print speed, and temperature. As shown in Fig. 24, the monitor page prototype displays the ongoing print tasks and their progress, allowing users to identify any issues that may arise during the printing process. Additionally, users can also pause or cancel the print job if necessary. Meanwhile, with the assistance of AI, the printer can automatically adjust the printing temperature or speed if the printer detects any issues or optimizes the print quality (Banadaki et al., 2020). The monitor page prototype is a crucial component of the 3D printing process, ensuring that users can monitor and manage their prints effectively to achieve the desired results.

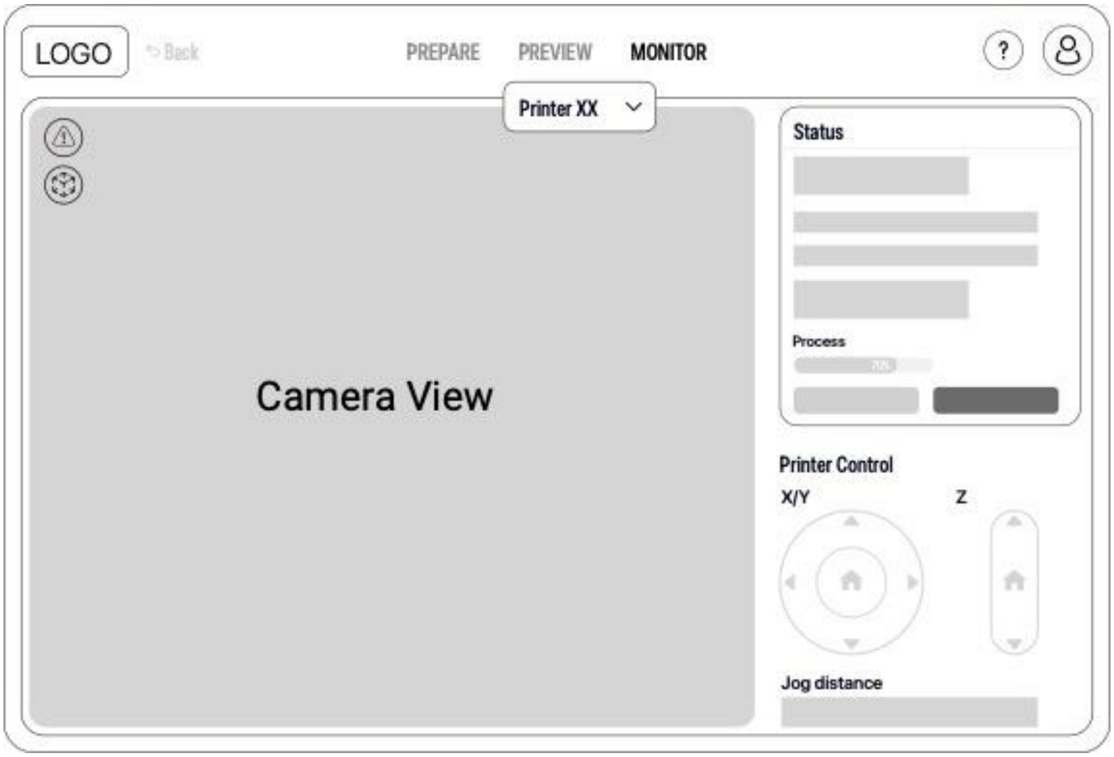


Figure 24. Monitor page prototype

7.2.6 Mobile platform prototype

A mobile platform prototype is a preliminary version or model of a software application designed for use on mobile devices, such as smartphones or tablets. This prototype is designed specifically for the unique features and capabilities of mobile devices, such as touch screens, smaller screen sizes, and limitations on mobile data usage.

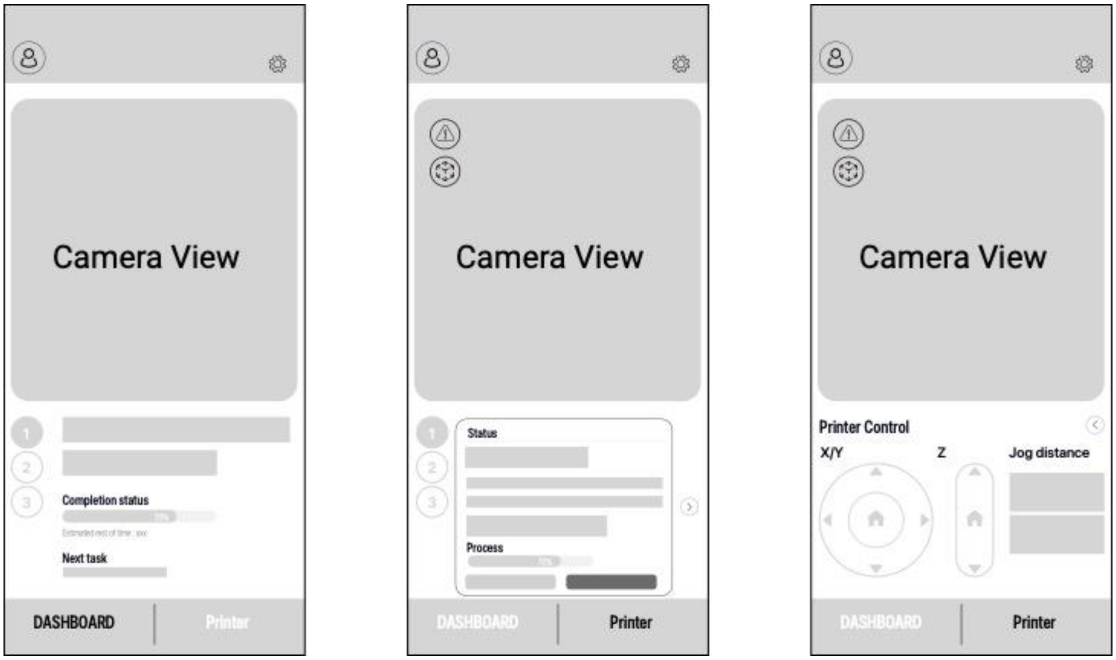


Figure 25. Mobile platform prototype

Mobile platform prototypes can be used to test and refine the user interface, features, and functions of mobile applications before the final release. It allows designers and developers to receive feedback from users and make necessary modifications to optimize the user experience, ensuring that mobile applications meet the needs and expectations of their target audience. This mobile prototype focuses on monitoring printing tasks since there are many operations required in 3D software that is better suited for computer-based operations, such as batch uploading files, clear model previews, and model error handling. Therefore, as shown in Fig. 25, the mobile prototype provides a simplified and intuitive interface for users to monitor the progress of their print jobs and take necessary actions such as pausing or canceling the print job if needed. This is helpful as the printing process can take many hours and is monitored remotely

All in all, software conceptualization and prototype design are key steps in any software development, including 3D printing software. This process starts from the conceptual stage, where the goals and functions of the software are defined. Subsequently, there is the prototype design stage, during which preliminary versions or models of various software components are developed and tested, such as dashboards, preparation pages, preview pages, and monitoring pages. Prototyping allows designers to refine and improve the functionality and user experience of the software before developing the final version. The use of prototypes helps identify potential issues and areas for improvement, ensuring that the final product meets user needs and expectations.

CHAPTER 8: FINAL DESIGN PROPOSAL

The final design proposal is crucial because it presents a complete and meticulous design plan for the 3D printing software, building on the concepts and prototypes developed in earlier stages. It offers a comprehensive summary of the features, functionalities, and technical specifications of the final product, along with a detailed outline of the user interface design. As follows, the design of each interface will be described in turn through the operation process of the software.

8.1 AI 3D Print Assistant

The intelligent assistant has emerged as a game-changer (Forrest & Hoanca, 1 C.E.) in the way humans interact with machines, especially when it comes to 3D printing technology. They offer an efficient and user-friendly interface that can bridge the gap between humans and machines, making complex technology more accessible to a wider audience.

Through natural and conversational language, chatbots can interact with users in a friendly and intuitive way, providing guidance and solutions to any issues that may arise during the 3D printing process. This means that users with little or no technical expertise can easily ask questions or seek assistance from the chatbot without feeling intimidated.

Furthermore, the chatbot's ability to use friendly language and deliver accurate information in real-time enhances the user experience by reducing the time and effort required to troubleshoot and solve problems. This not only helps users to overcome obstacles but also builds trust and confidence in the technology.

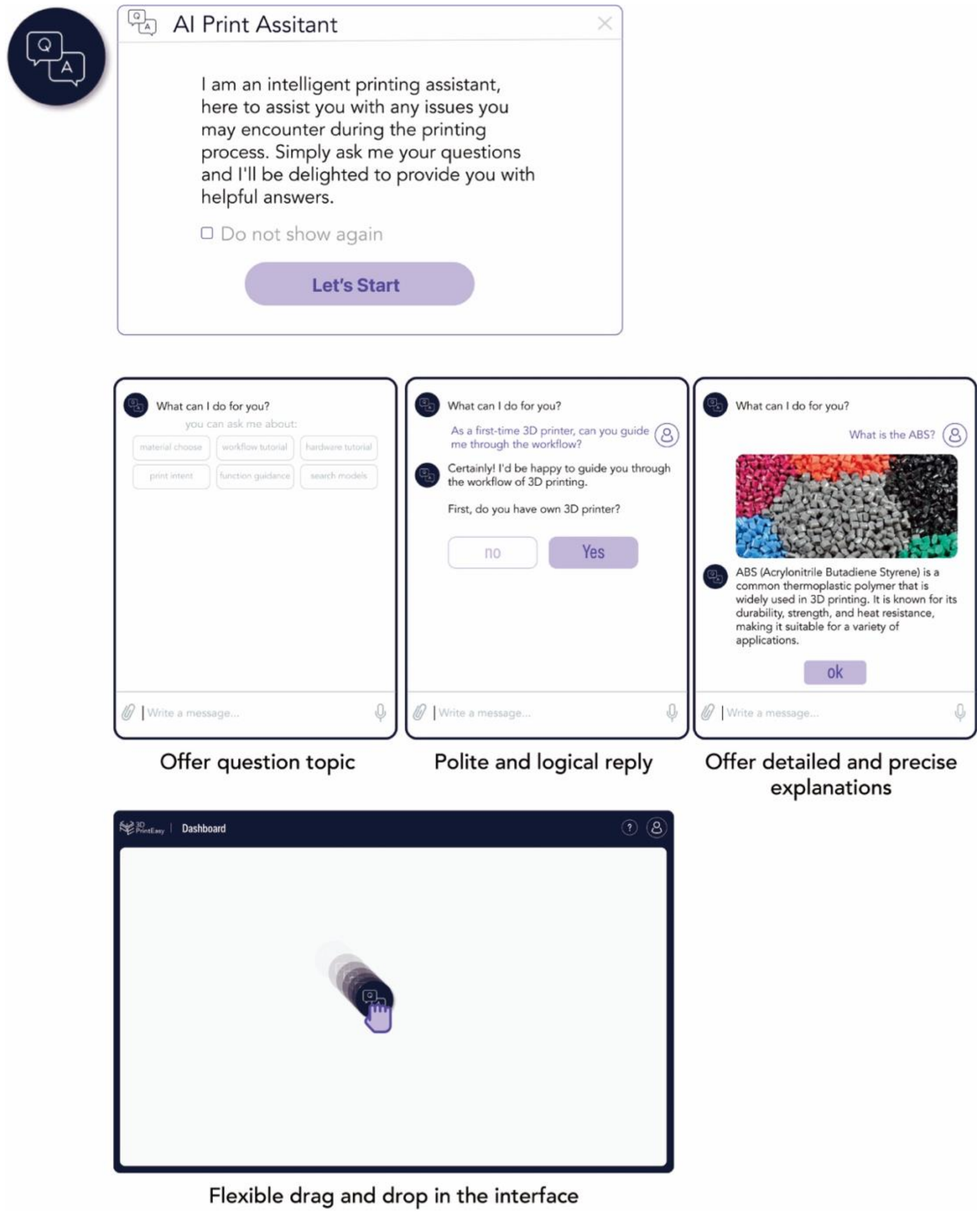


Figure 26. AI 3D Print Assistant

Fig. 26 provides an example of how an intelligent chatbot can quickly provide users with the information they need without using unnecessary jargon or technical terms. The chatbot uses friendly and straightforward language to explain the steps involved in the 3D printing process, making it easier for users to understand and execute.

Overall, the use of intelligent chatbots as human-machine interfaces for 3D printing is a promising trend that can revolutionize the way users engage with this technology. By simplifying the process and making it more accessible, chatbots can help drive innovation and promote wider adoption of 3D printing in various industries, opening up new opportunities for growth and development.

8.2 Start stage

To start using the 3D printing software, the user must first open the application (as shown in Fig. 27). Once opened, the user will be presented with a login page that offers two options - registering for an account or logging in as a guest. This step is necessary to ensure that the user's data is secure and that they have access to all of the software's features. In addition, users are introduced to the software's artificial intelligence assistant, which will act as a helpful guide throughout the printing process. The AI assistant is designed to help and guide users in a conversational and intuitive manner. Users will be prompted to activate the AI assistant and then have access to it throughout their use of the software.

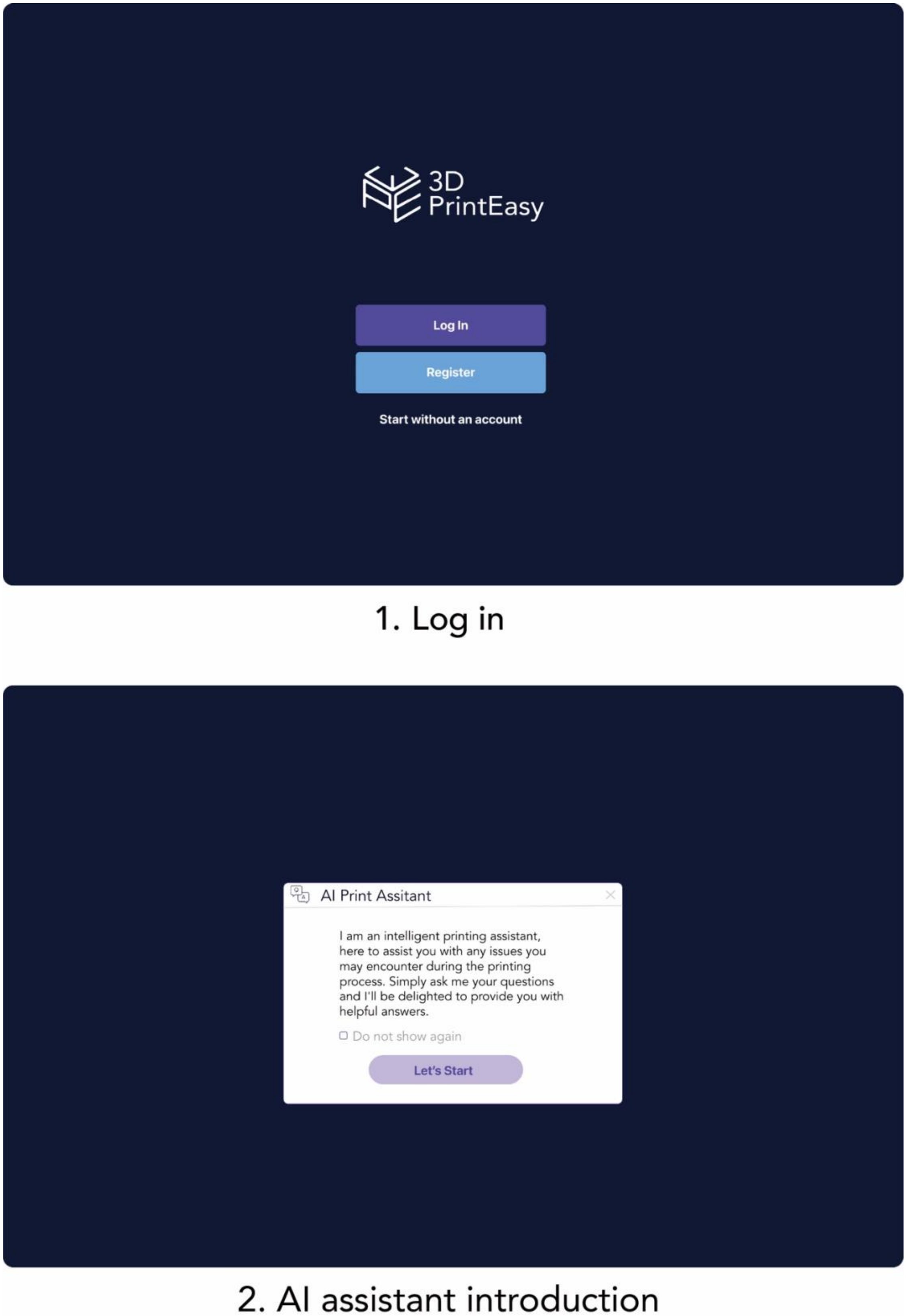
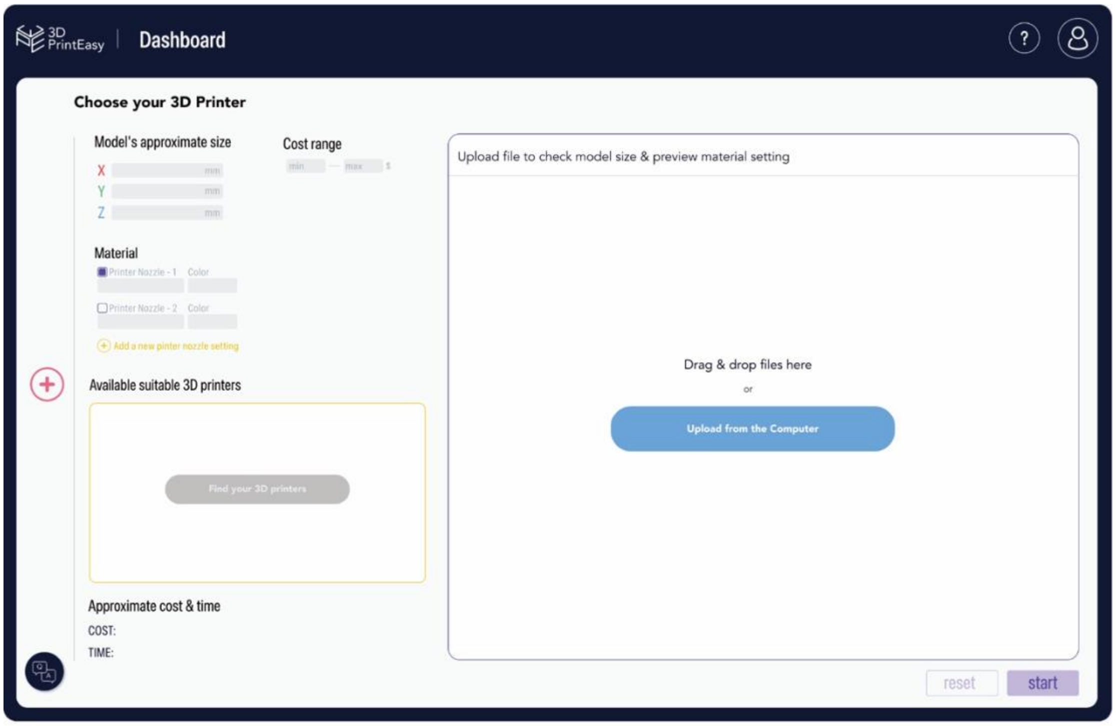
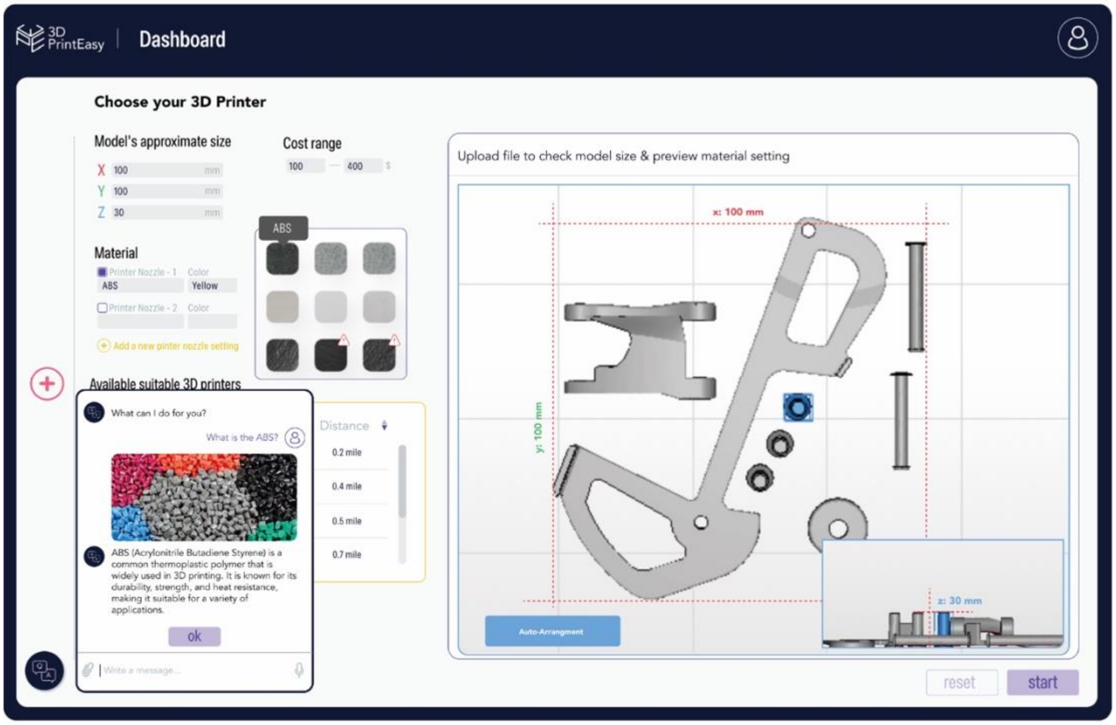


Figure 27. Open the software

To ensure that the 3D printing process is successful, it's crucial for the user to select the appropriate printer. To make this process more efficient, the software provides several useful features. Firstly, users can preview the size of their uploaded file, and then select a suitable printer size that matches their needs. Additionally, the software suggests compatible 3D printers based on the user's budget, which can be especially helpful for beginners. Moreover, to make the decision-making process even more seamless, the software also displays a visual representation of the available printing materials, allowing users to choose the right material for their project. An example of this feature in action can be seen in Fig. 28.

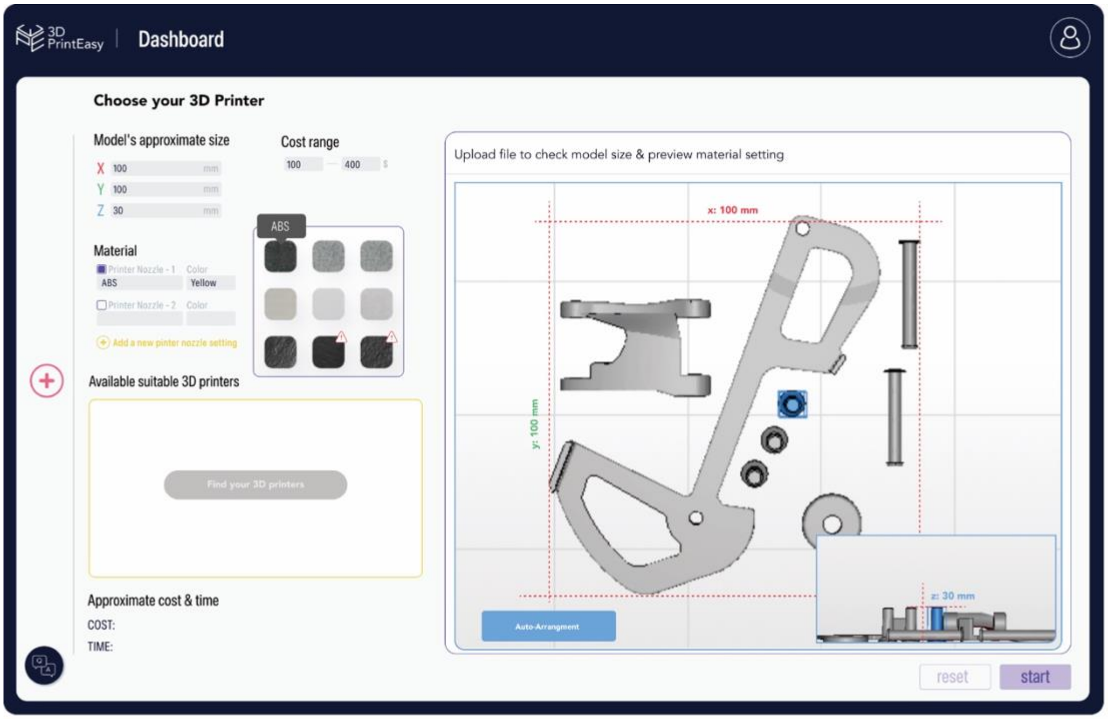


1. Upload files to get model size

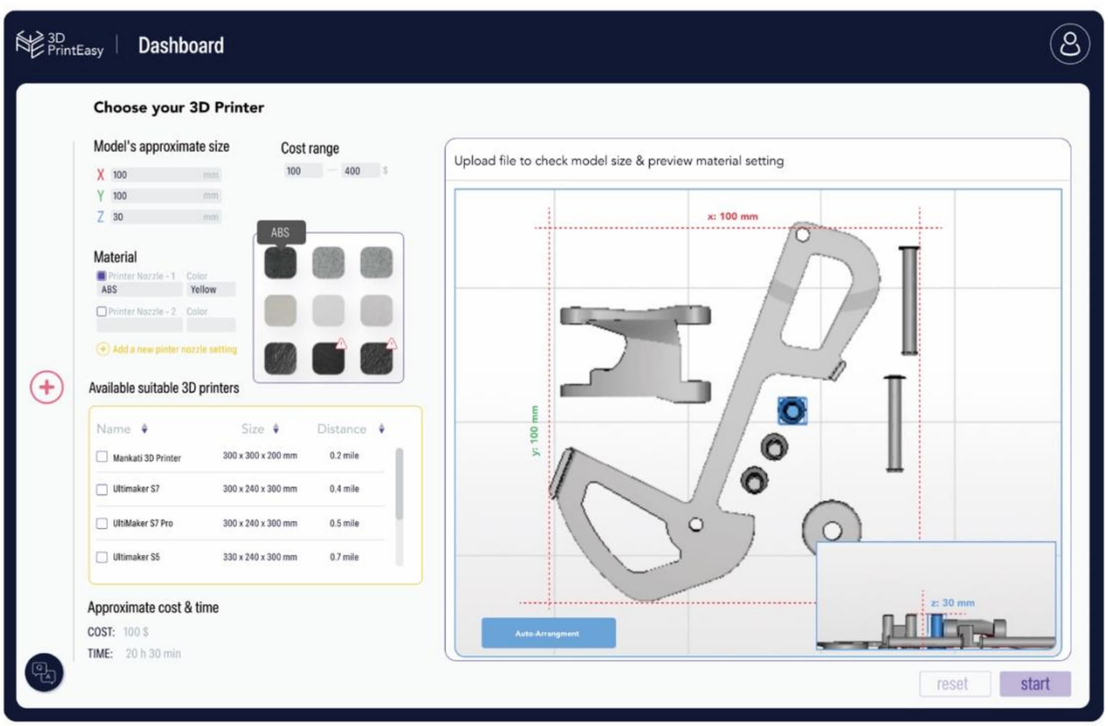


2. AI-Assist introduces various materials

Figure 28. Choose 3D printer



3. Find suitable and available 3D printers



4. Get approximate cost and time

Figure 28 (cont.)

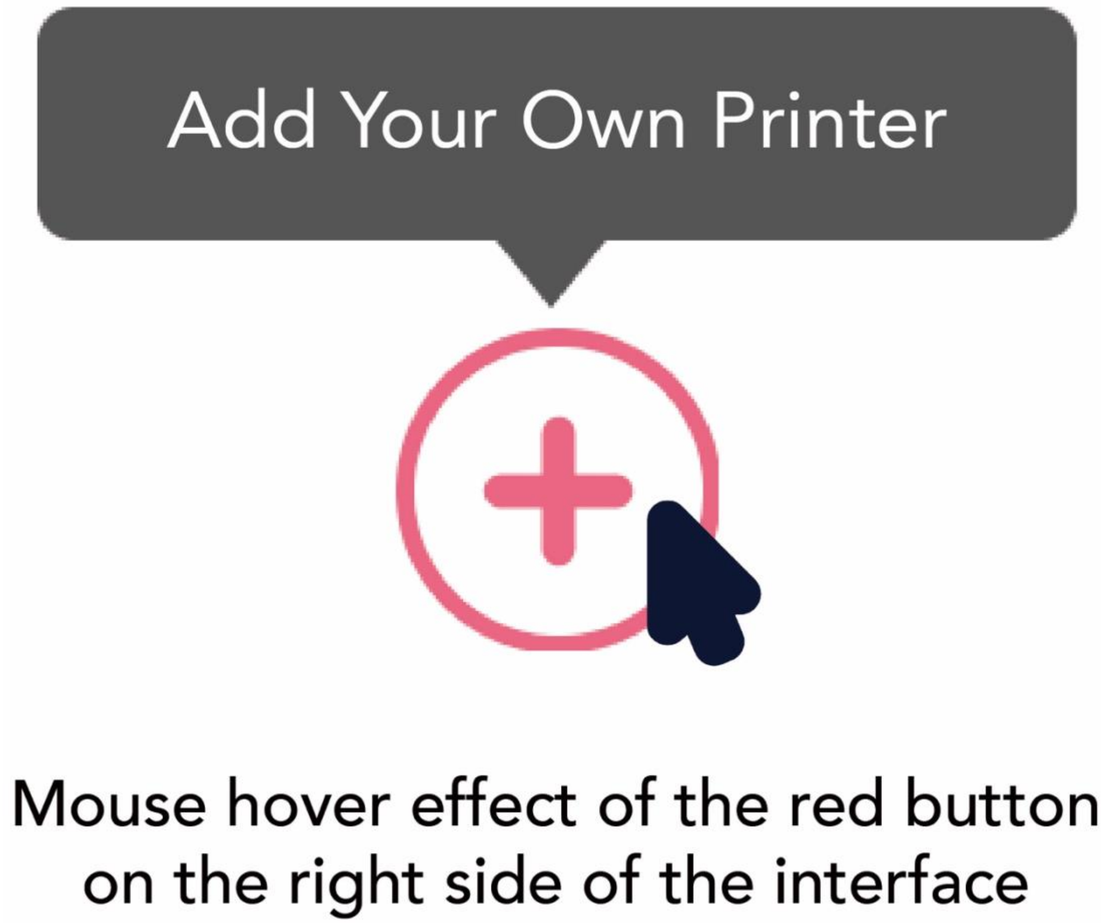


Figure 28 (cont.)

8.3 Prepare stage

To enhance the user experience, the preparation interface has been optimized for ease of use and simplicity. As shown in Fig. 29, with a clean and concise layout, the 3D rendering of the model takes center stage, with the surrounding buttons and menus arranged to minimize confusion and interference. To access the main functions, such as uploading files or modifying printing parameters, users can simply click on the square button located at the bottom of the screen. This button acts as a hub for all the core functions and settings, providing convenient access and intuitive control. The circular buttons located around the model enable users to adjust the spatial positioning of the model, such as moving, rotating, or mirroring it in different directions. These buttons are designed to be easily distinguishable and user-friendly, with clear visual cues that convey their functions.

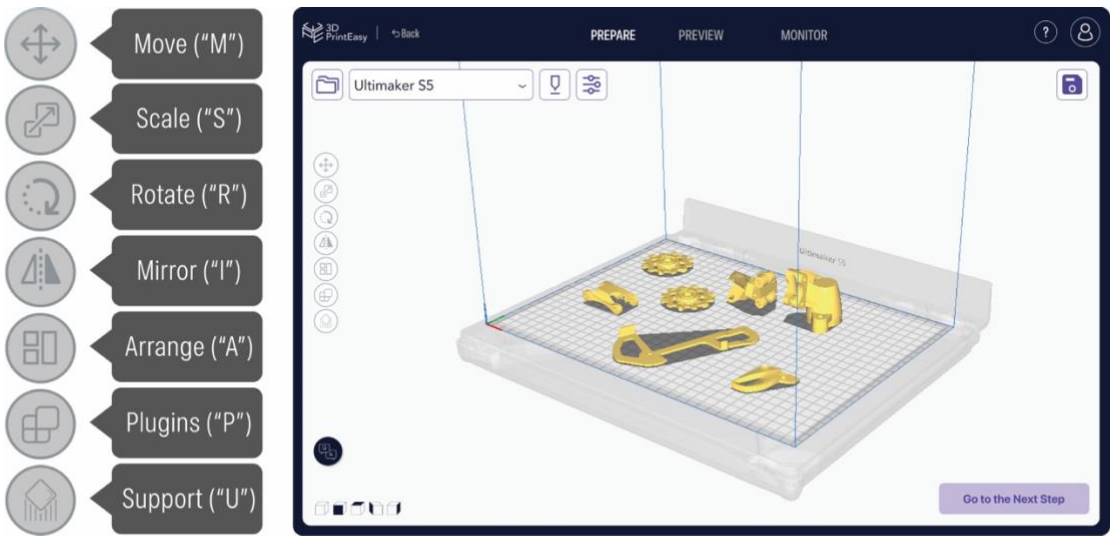


Figure 29. The prepare main page

In addition, in the event that the user's newly uploaded model size is too large (as shown in Fig. 30), the intelligent AI assistant integrated within the software will immediately intervene to provide assistance. The AI assistant will notify the user of the issue and offer possible solutions to help them overcome the problem. For instance, the AI assistant may suggest scaling the file size of the model or changing other printers.

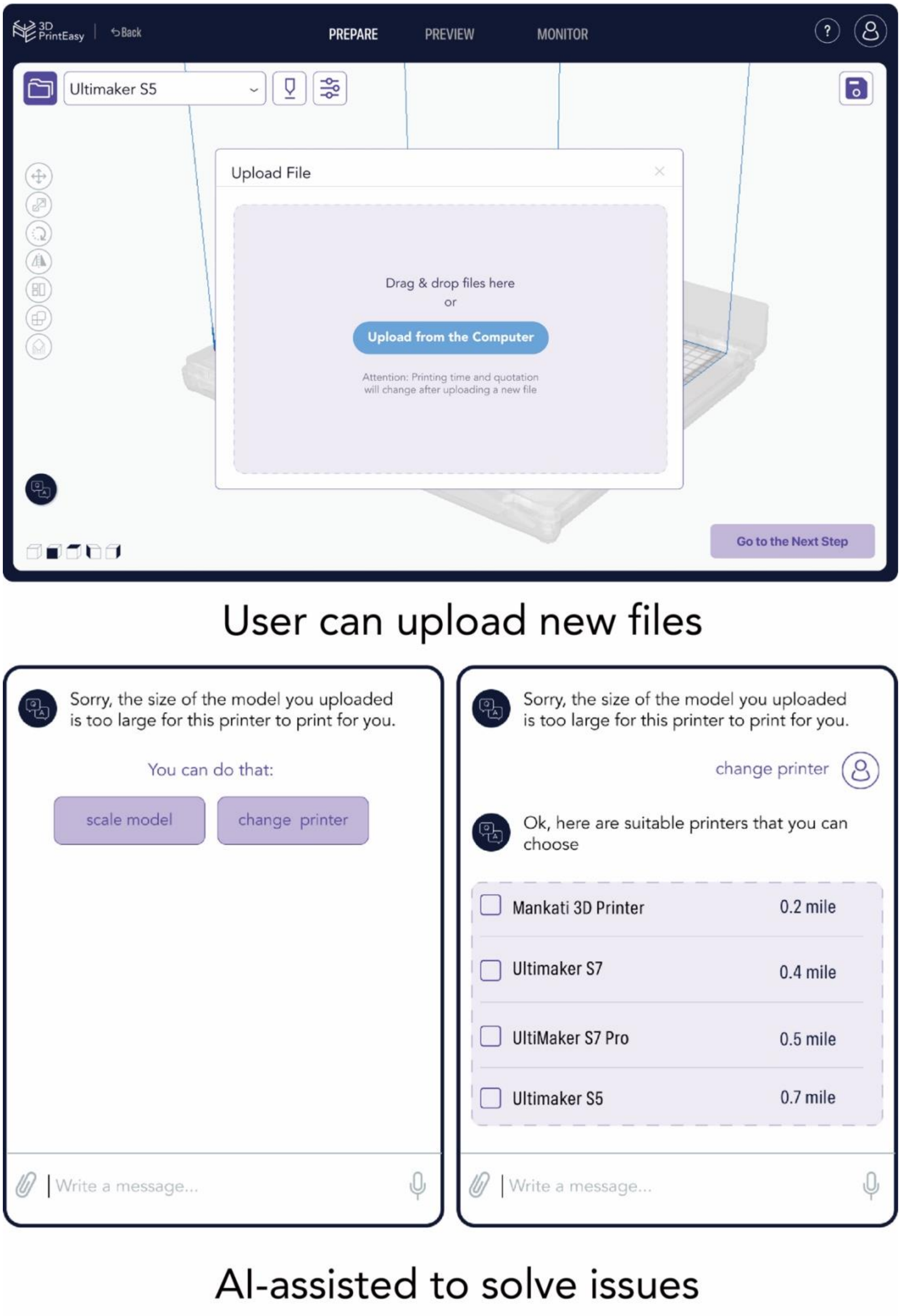


Figure 30. The upload model size is too large

The prompt intervention of the AI assistant in such a situation is intended to ensure that the user does not encounter any obstacles or delays during the 3D printing process. This feature is particularly useful for users who may not have experience with 3D modeling or are unfamiliar with the software's parameters and limitations. By providing a timely and effective response to this problem, the software demonstrates its commitment to ensuring that users have a seamless and productive experience when using the software. This approach promotes user satisfaction and fosters greater adoption of the software within the 3D printing community.

The next step is the print head setting, where users can make detailed adjustments to the printhead, ensuring optimal printing quality and material compatibility. As shown in Fig. 31, the interface is designed to be user-friendly and informative, with clear visual representations of each parameter and option.

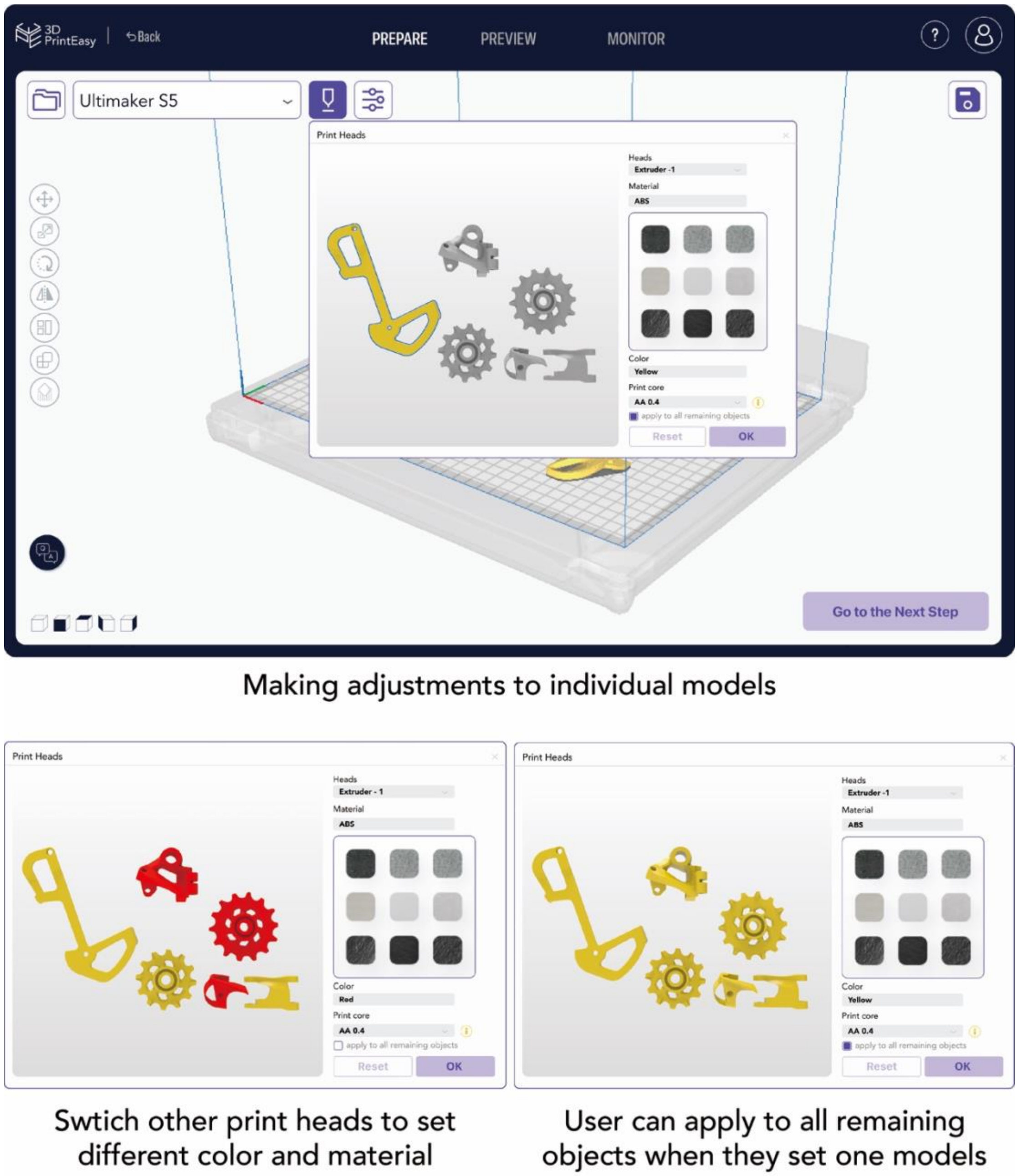


Figure 31. The print head setting for the digital models above

Moreover, the software allows users to save their settings, which can be convenient for those who have specific preferences or requirements for their prints (as shown in Fig. 32). By saving the settings, users can avoid the hassle of having to manually adjust them every time they use the software. This feature is particularly useful when users need to produce a large number of prints with similar settings. With just a few clicks, users can quickly replicate their preferred settings for each print job, saving time and ensuring consistency.

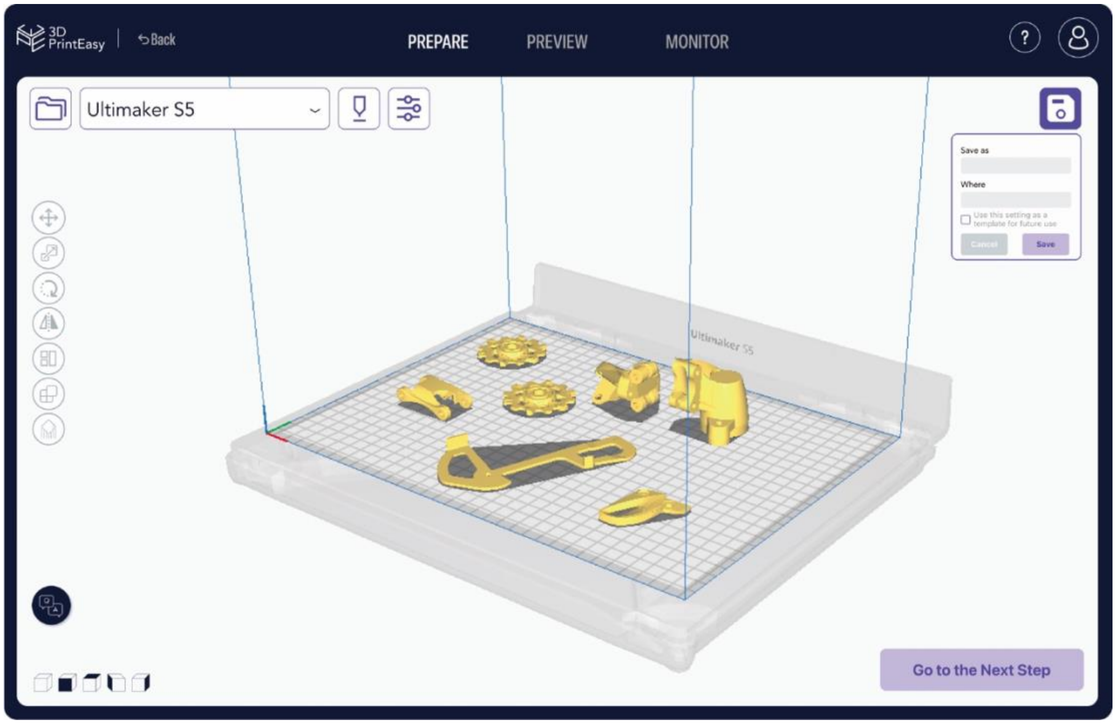


Figure 32. Save the file and settings

Meanwhile, the software is specifically designed to empower users with the ability to make precise and detailed adjustments (as shown in Fig. 33), enabling them to achieve their desired results with ease. The user-friendly interface and intuitive controls of the software ensure that users can quickly and efficiently modify various settings to fine-tune their prints. By providing users with the tools and capabilities to fine-tune their prints, the software aims to deliver an exceptional user experience that promotes creativity, innovation, and success in 3D printing.

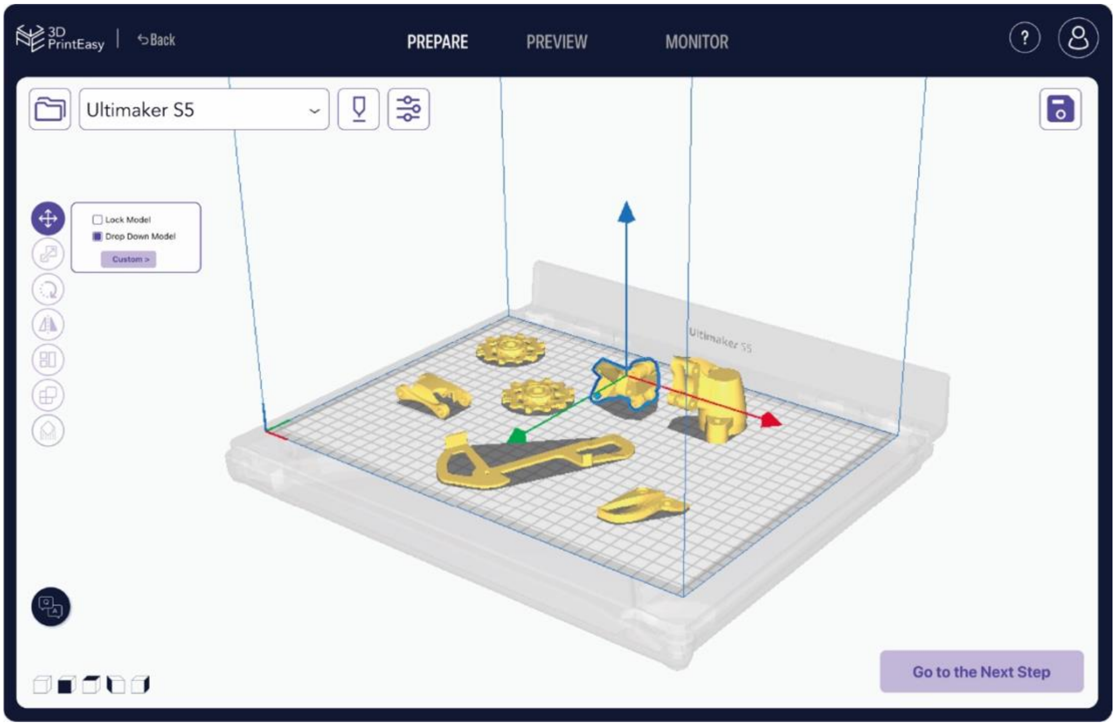
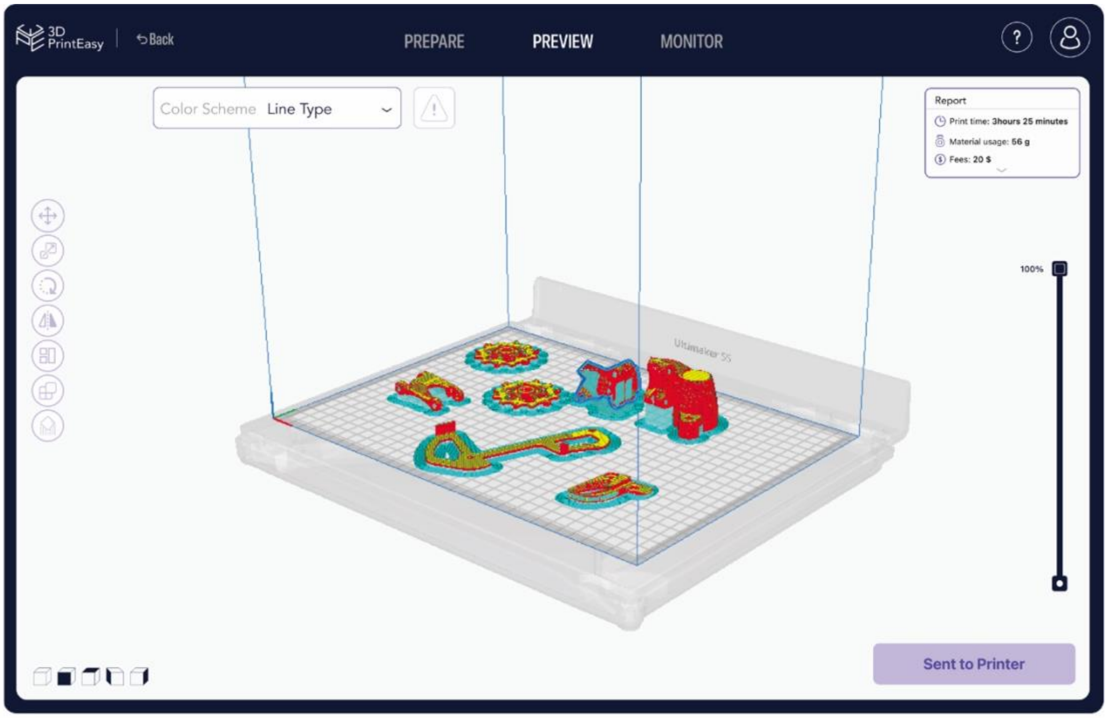


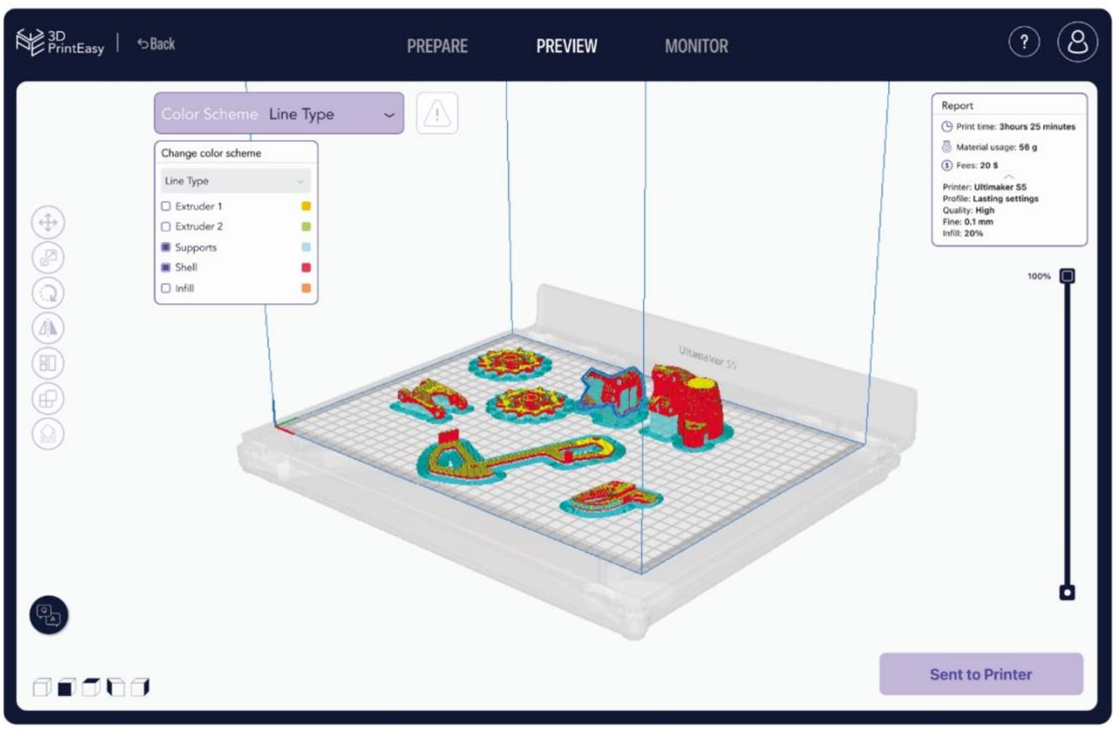
Figure 33. Do detail the adjustment (e.g., placement and model size)

8.4 Preview stage

The software utilizes a color-coded system to represent different layers of the model (as illustrated in Fig. 34). This provides users with a convenient preview function, enabling them to visually evaluate the printing effect after model adjustments before printing the actual model. The software also eliminates some insignificant information, creating a minimalist interface.



Preview page main view



1. Check view

Figure 34. The preview stage

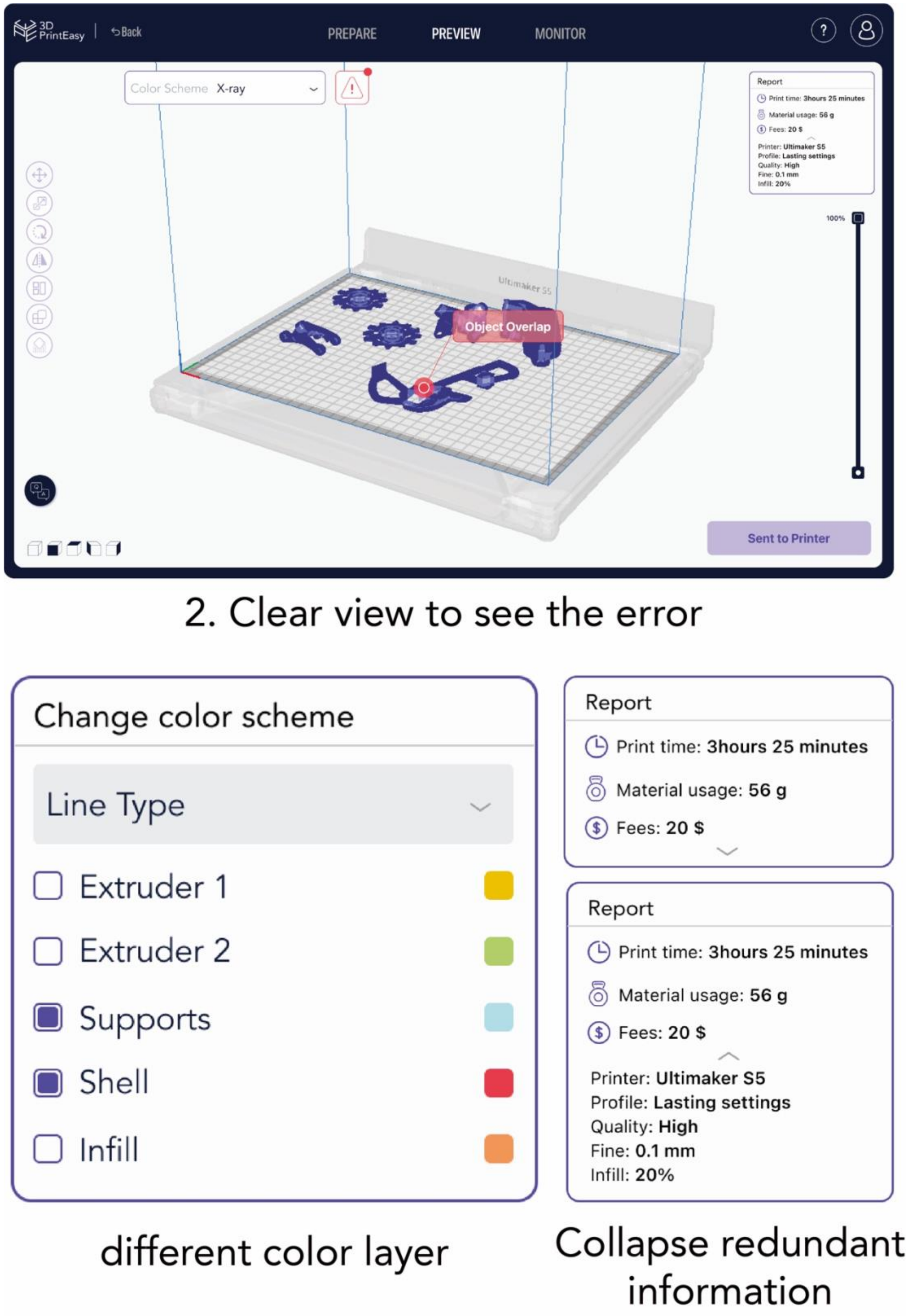


Figure 34 (cont.)

By using the preview function, users can detect any potential issues or errors in advance, allowing them to make necessary adjustments to achieve the expected results. Additionally, if an error occurs during the printing process (as shown in Fig. 34 (2)), the software provides clear and detailed error information. This allows users to quickly diagnose problems and take appropriate actions to correct them, minimizing downtime and improving overall efficiency.

The software's intuitive interface and user-friendly preview function make it easy for users to achieve the desired printing results. The advanced error detection system also ensures that any printing issues are quickly identified and resolved, reducing wasted time and resources. Overall, the software provides a streamlined and efficient printing experience for users, helping them to achieve their desired outcomes with ease.

8.5 Printing stage

In the printing phase, the software provides a monitoring interface for users to make adjustments to the 3D printer before printing and to monitor the printing process in real-time (as shown in Fig. 35). Users can use the control panel to further adjust the printer. At the same time, the interface displays specific information about the printing task, making it easy for users to view. Moreover, the software is designed to enhance the user experience by incorporating augmented reality (AR) technology to assist with printer adjustments (as shown in Fig. 36). With AR, users can easily visualize how to optimize the positioning of their printer, making it easier to fine-tune and achieve the desired results.

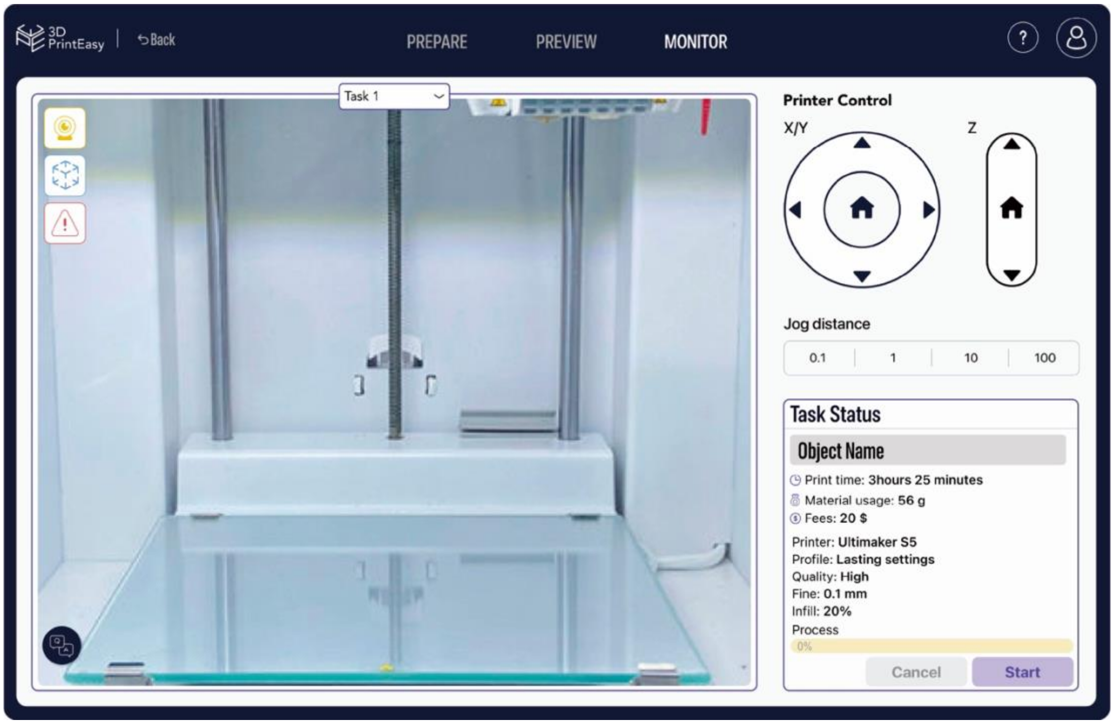


Figure 35. Monitor page

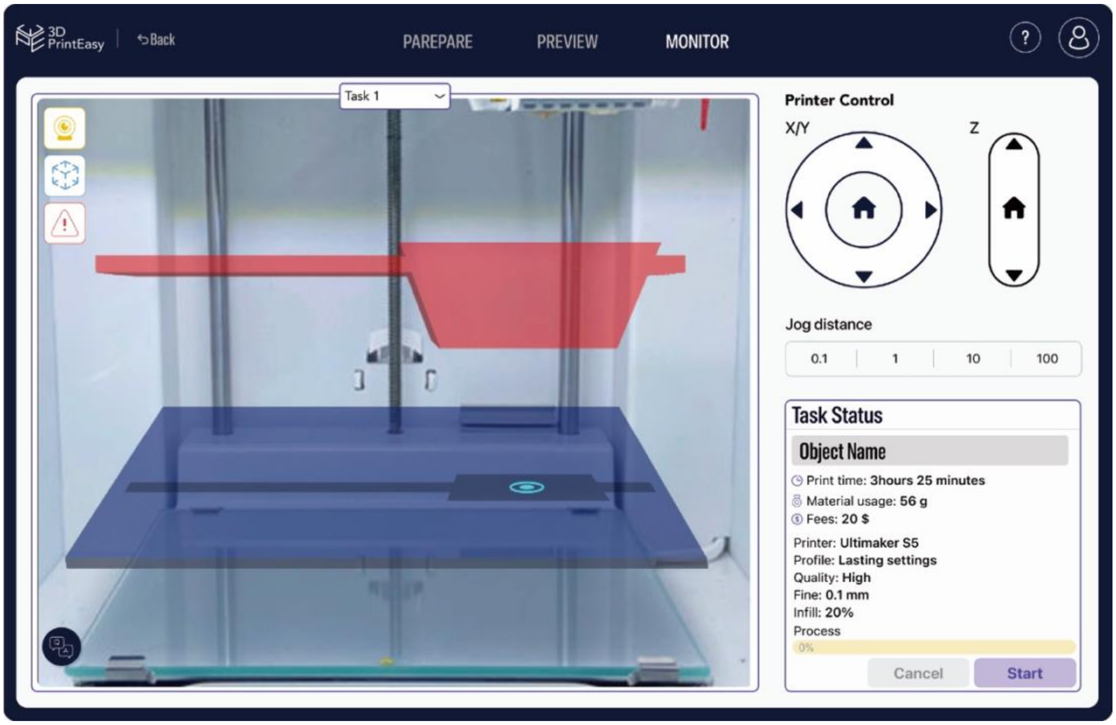


Figure 36. AR view

In addition, the software provides the flexibility to switch between different viewing modes, allowing users to select the view that best suits their needs (as shown in Fig. 37) without the need for extensive training or expertise.

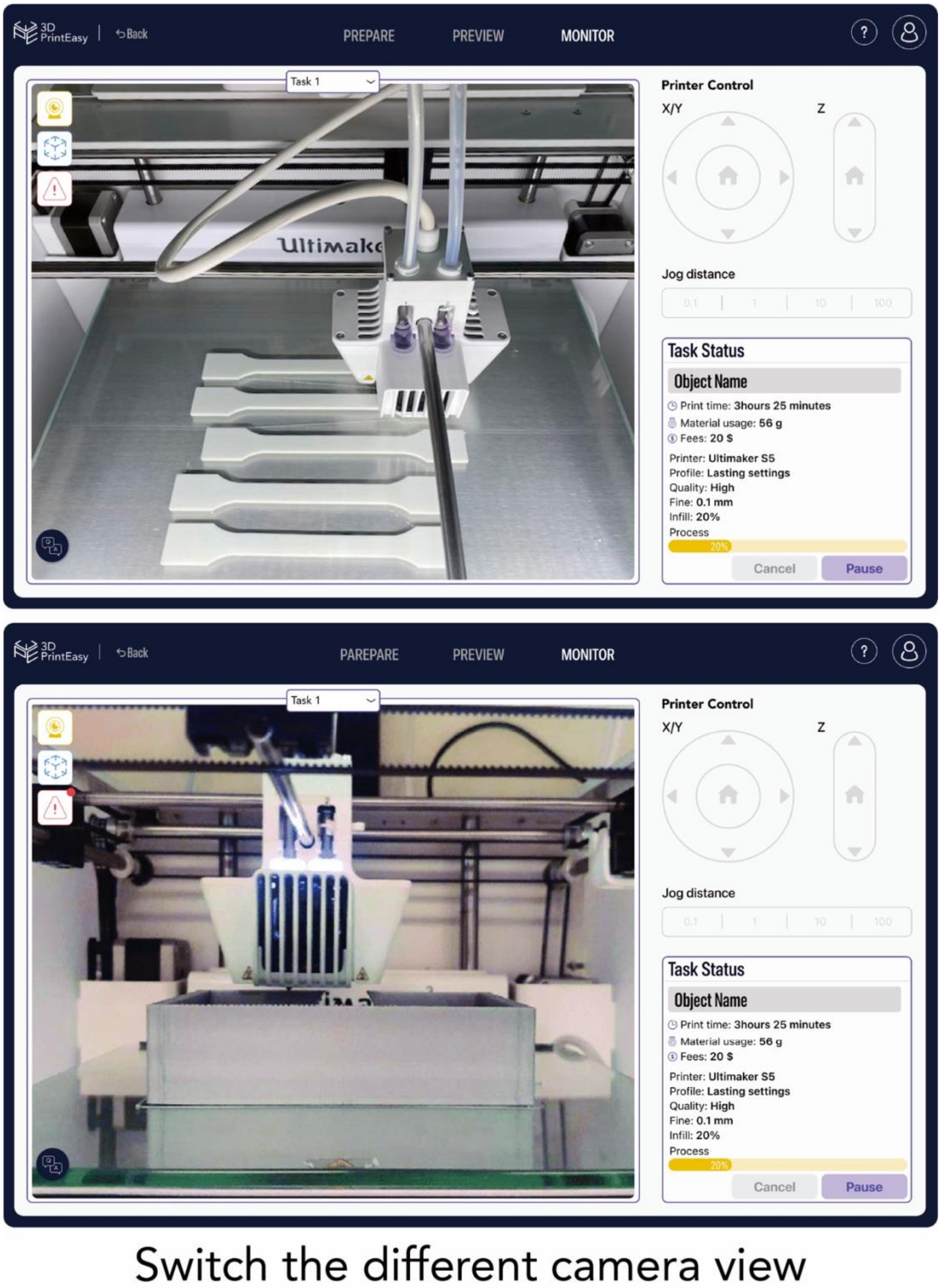


Figure 37. Switch the different camera view

Moreover, if an error occurs during the printing process, the software will inform users and the AR technology can help users diagnose the issue and provide suggested solutions (as shown in Fig. 38). By leveraging this technology, users can quickly and easily address any issues that may arise, minimizing downtime and ensuring optimal printing results.

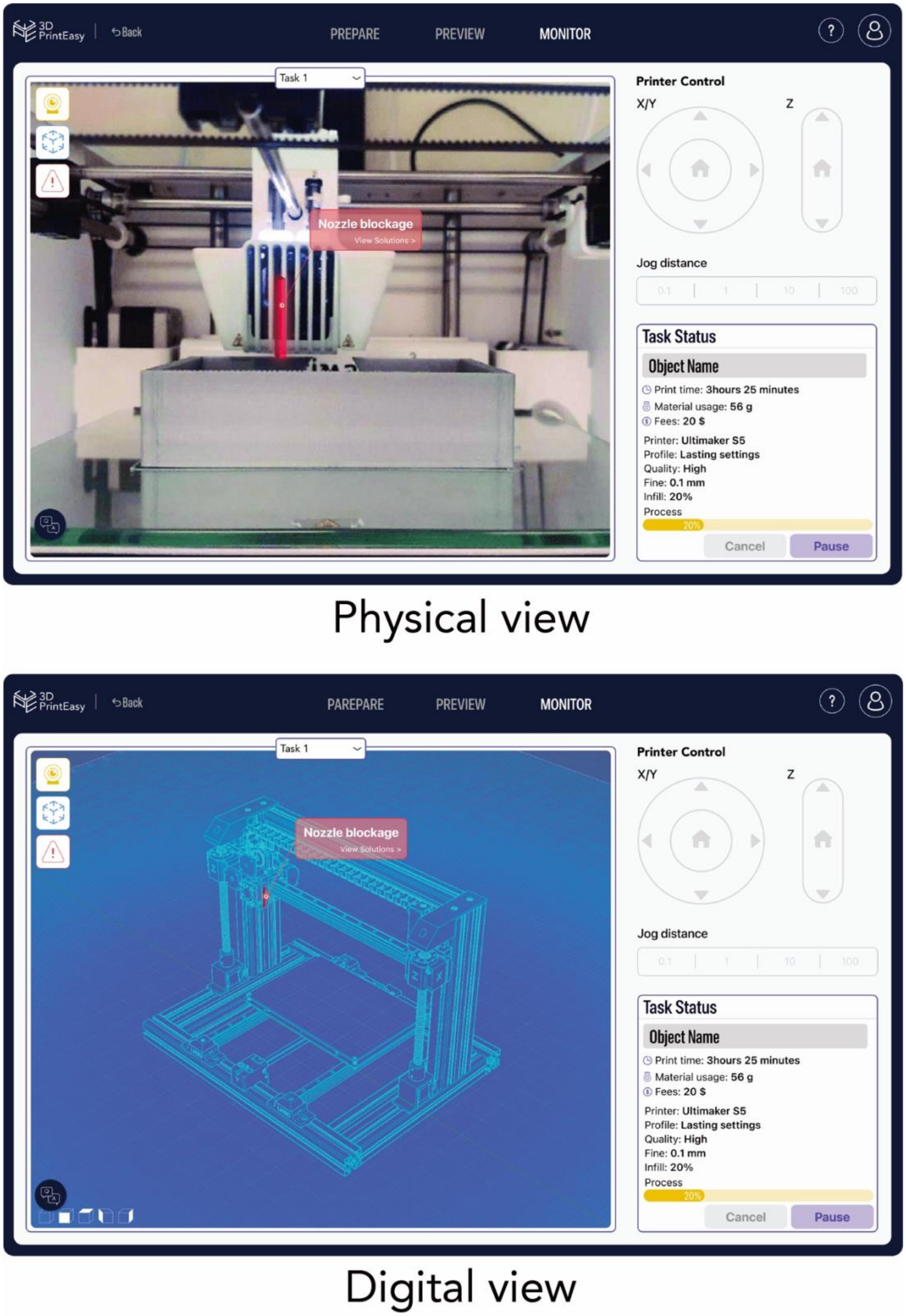


Figure 38. AR view to find the error part

8.6 Printing stage – Dashboard

The dashboard features a highly intuitive user interface that allows users to easily manage multiple tasks and view important details with ease (as shown in Fig. 39). With a focus on user-friendliness, the software interface has been designed to be as intuitive and straightforward as possible, making it accessible for users of all skill levels.

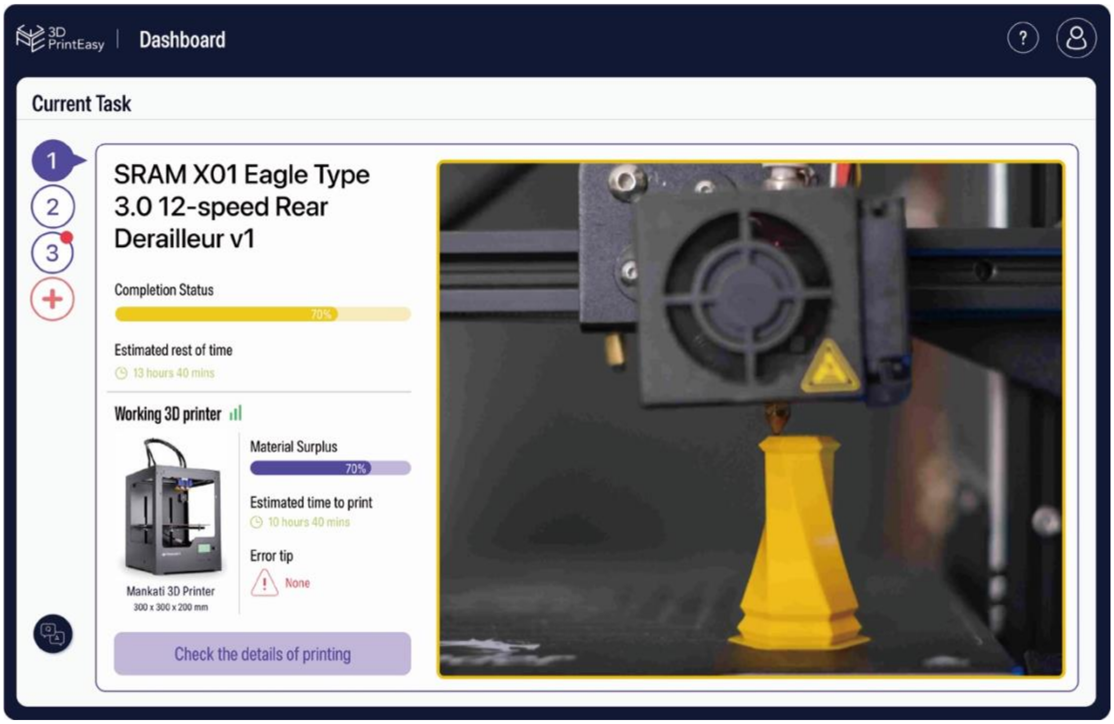


Figure 39. The dashboard

The interface provides clear and concise access to all key functions, making it easy to navigate and find the tools you need. Additionally, the interface has been designed with a focus on maximizing screen real estate, ensuring that users can easily view and manage their projects. What’s more, if an error occurs during the printing process, the AI assistant can help users save time and material by promptly pausing the print job and notifying them of the issue. By taking swift action to address the error, users can avoid wasting additional materials and time on a failed print (as shown in Fig. 40).

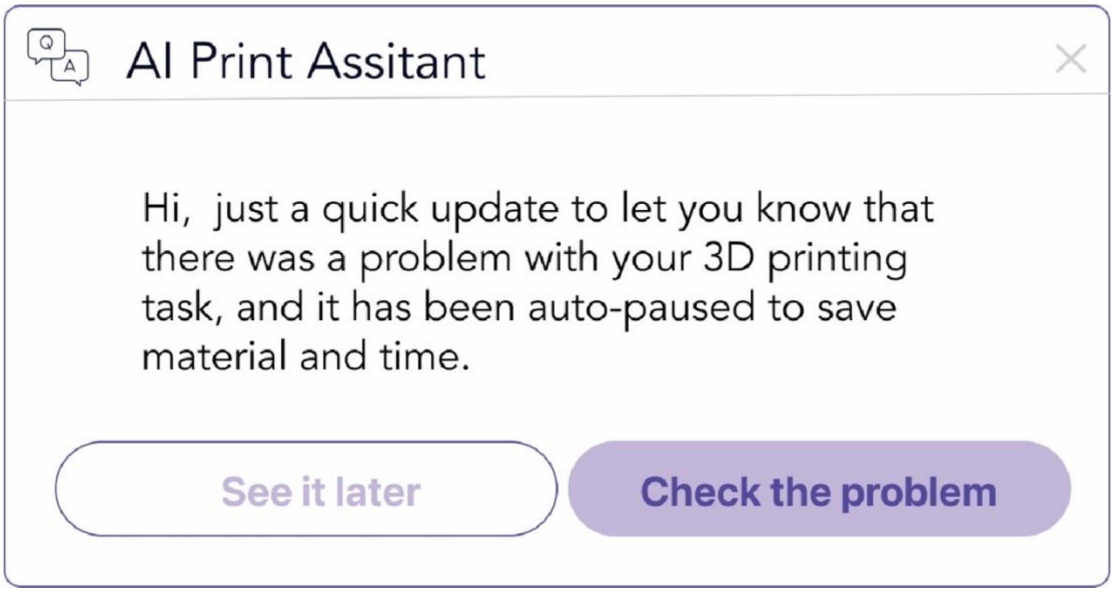


Figure 40. AI-assist to inform the printing error

In addition, the software also offers a mobile platform specifically designed for monitoring and adjusting the printing process according to the user's specific needs (as shown in Fig. 41). The mobile version provides users with real-time monitoring of the printing process, allowing them to remotely adjust printing settings and make necessary modifications to the model design. By offering this level of flexibility and accessibility, the mobile platform enables users to optimize the printing process even when they are away from the printing site.

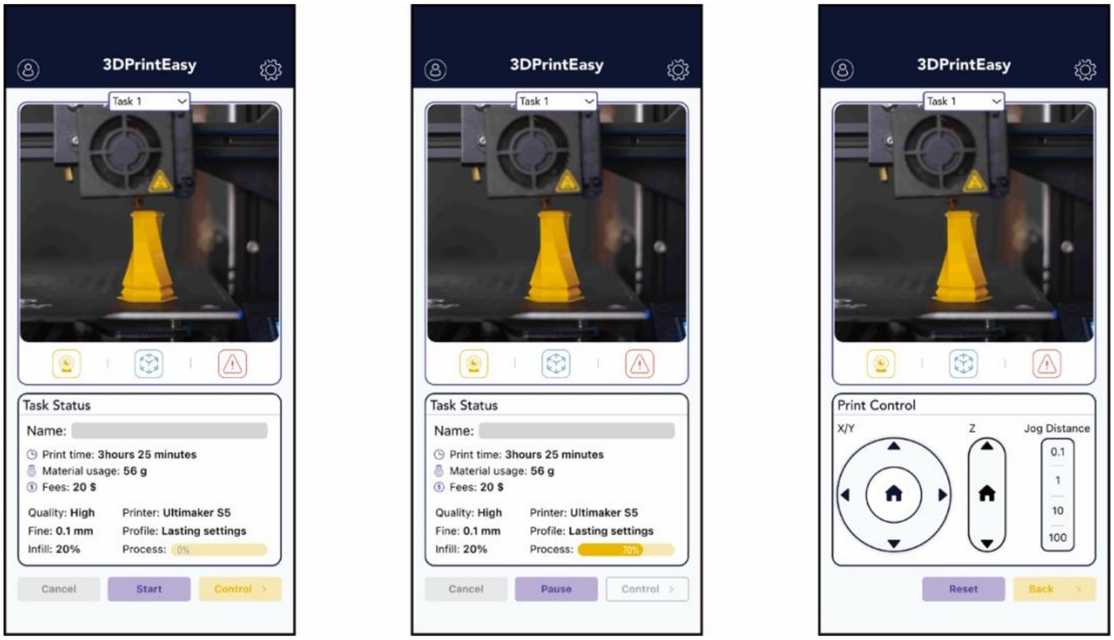


Figure 41. The mobile platform

8.7 End stage

In the final stage of the printing process, the software's intelligent assistant plays a crucial role in keeping the user informed about the status of the print job. Once the job has been completed, the intelligent assistant notifies the user in friendly language that the print job is finished and ready for removal (as shown in Fig. 42). This notification is especially helpful in cases where the user may not be physically present at the printing site and needs to monitor the progress remotely. By providing clear and timely updates, the software's intelligent assistant ensures that the user is aware of the completion status and can take appropriate actions to retrieve the finished product in a timely manner.

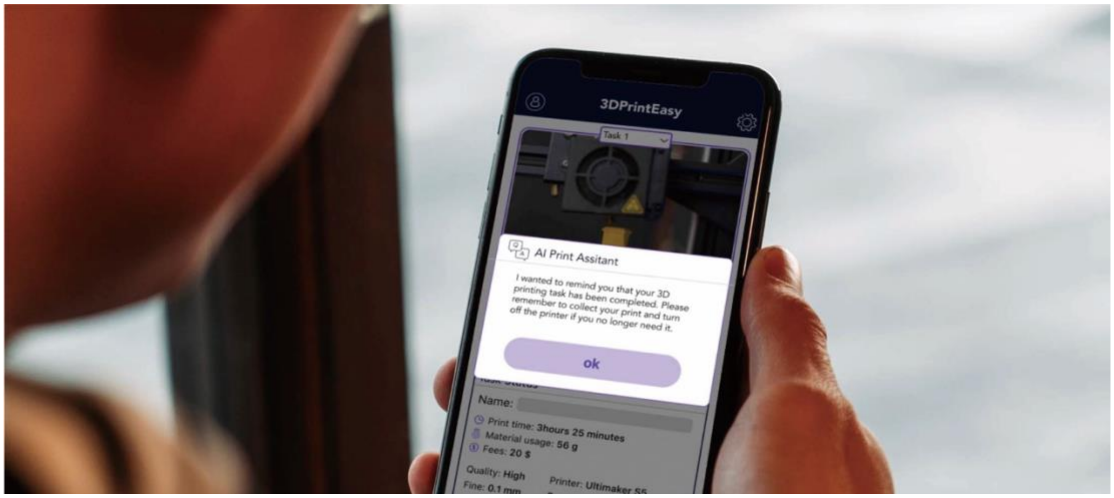


Figure 42. Remind users that printing is complete

Moreover, the friendly language used by the intelligent assistant makes the entire printing process more approachable and less intimidating for users, especially those who may not be experienced with 3D printing. The language used by the assistant is designed to be easy to understand and non-technical, ensuring that users of all skill levels can navigate the printing process with confidence. Overall, the software's intelligent assistant provides a seamless and user-friendly experience for 3D printing, from start to finish.

CHAPTER 9: DISCUSSION AND FUTURE WORK

The design and implementation of the 3D printing software have demonstrated several proposed benefits to users. By employing a user-centric approach, the project created an intuitive and user-friendly interface that enables users to navigate the software's functions. In addition, the integration of artificial intelligence assistants further enhances the user experience by providing guidance and troubleshooting assistance during the printing process. To assess the effectiveness of the software, several users tested it (as shown in Fig. 43), and their feedback was overwhelmingly positive, remarking on the software's ease of use, comprehensive functions, and ability to simplify their workflow and improve their efficiency in 3D printing.

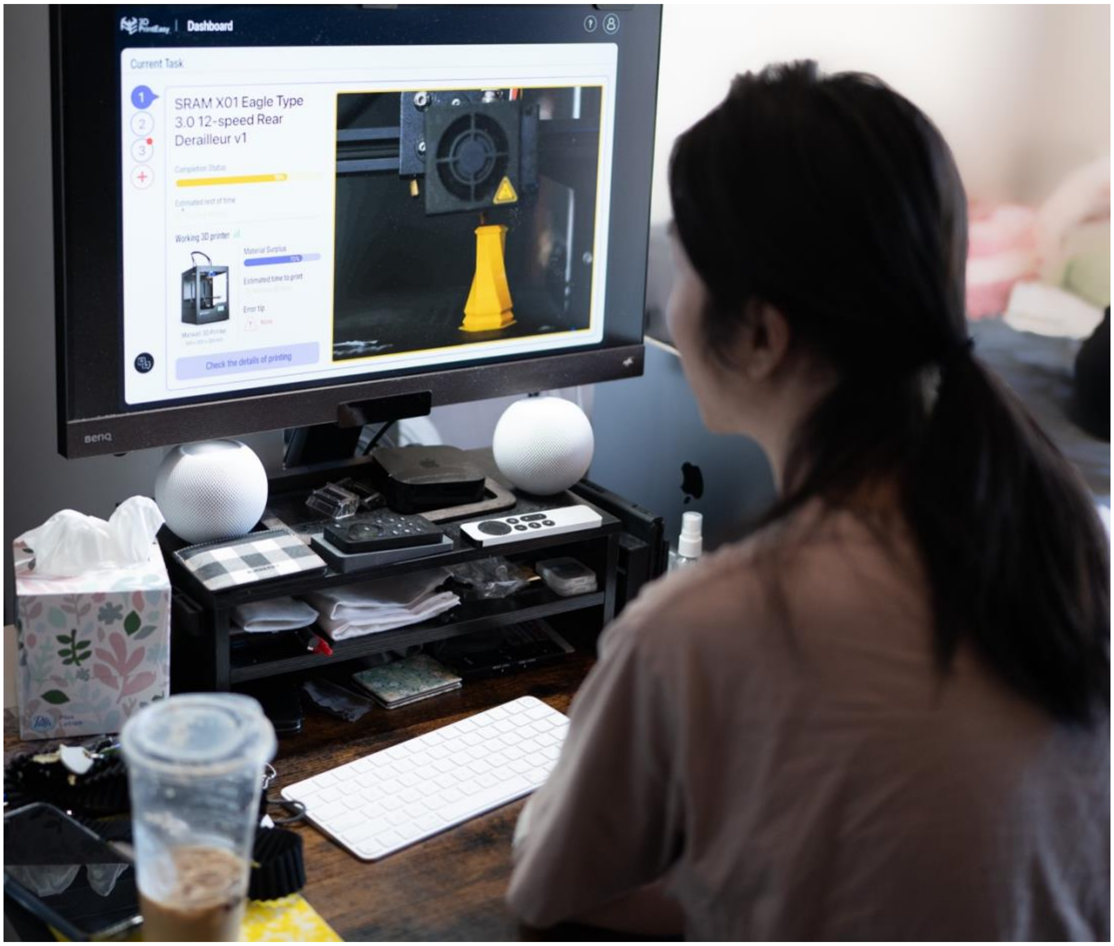


Figure 43. User test

However, some users have also identified certain areas for improvement. For instance, some users reported that the AR assistance may not be effective if the nozzle is too close to the printer platform when adjusting a 3D printer. Therefore, in the future, to address the identified areas of improvement and further enhance the user experience, several future works can be considered. One potential improvement is the addition of more detailed user guides or tutorials in the conversational AI assistant to help users better understand the software's features and functionalities. Furthermore, integrating more advanced features such as automatic error detection and correction or augmented reality visualization could improve the user experience and expand the software's capabilities.

Overall, the development of this 3D printing software represents a significant step forward in making 3D printing technology more accessible and user-friendly. With continued efforts towards improvement and expansion, this software has the potential to revolutionize the 3D printing industry and pave the way for new applications and innovations.

CHAPTER 10: CONCLUSIONS

In conclusion, 3D printing technology is transforming the manufacturing industry (Praveena et al., 2022), offering an efficient and cost-effective way to create complex designs and prototypes with minimal waste during some manufacturing processes. However, despite its popularity, the technology can be challenging for beginners due to the complexity of the software user interfaces and the various issues that can arise during the printing process. To make 3D printing more accessible to beginners and increase the market volume of 3D printers, researchers have been exploring ways to enhance the digital capabilities of 3D printing.

One promising area of focus is the integration of artificial intelligence and augmented reality technologies into 3D printing software to improve user experience and accessibility. By leveraging AI and AR technologies, a new software proposed in this study offers an interactive, user-friendly interface that guides beginners through the 3D printing process and offers real-time feedback to improve their prints. The software also includes a conversational assistant that can answer user questions and provide helpful tips along the way.

The integration of AI and AR technologies into 3D printing software not only makes the technology more accessible for beginners but also improves overall manufacturing efficiency. With the ability to project virtual objects onto the physical environment and enable thorough observation and understanding by users, AR technology can significantly enhance the manufacturing process. Meanwhile, AI technology can provide intelligent guidance and assistance to beginners who may lack technical expertise. These technologies have the potential to revolutionize the way beginners learn and interact with 3D printing technology. All in all, the new proposed software aims to enhance the accessibility and usability of 3D printing technology for beginners by integrating AI and AR technologies into the software design.

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APPENDIX A- Core IRB Training Certification

Core IRB Training Certification

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