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Visual-based CAD Education for hearing Inclusivity

Mr. Siyuan Meng, University of Southern California

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Siyuan Meng
siyuanm@usc.edu
Department of Aerospace and Mechanical Engineering
University of Southern California

Robert Pan
wenzhuop@usc.edu
Department of Aerospace and Mechanical Engineering
University of Southern California

Elizabeth Finley
edfinley@usc.edu
Department of Aerospace and Mechanical Engineering
University of Southern California

Bocheng Jin
bochengj@usc.edu
Department of Aerospace and Mechanical Engineering
University of Southern California

Abstract

A specialized adaptation of a Computer-Aided Design (CAD) curriculum was developed to provide hearing-impaired students with equitable access to learning and to foster an inclusive educational environment. This curriculum emphasizes visual-based instruction to familiarize students with the functionalities and limitations of CAD software, foundational design processes, and effective collaboration with other engineers using these tools. Traditional video and audio recordings are often inaccessible for hearing-impaired students when reviewing course material. To address this, the teaching method relies on purely visual, step-by-step instructions consisting of images and text. Teaching assistants meticulously create these instructions from the course content, using sequential screenshots of software operations paired with descriptive text. This approach ensures that students can effectively understand, review, and revisit the material through a fully visual learning experience. Each instruction set also includes detailed explanations of specific software operations. For this course, step-by-step guides were developed for two key topics: (1) kinematics simulation and (2) engineering drawing, using Siemens NX software.

Visual instruction will be provided to hearing-impaired students before lecture and student's feedback is discussed in the discussion section. This method significantly enhances the learning efficiency of hearing-impaired students, helping them overcome barriers posed by hearing limitations. In this study, the proposed method was implemented in a CAD course for a hearing-impaired student. Two teaching assistants (TAs) created purely visual, step-by-step instructions tailored for the student's use. This approach significantly improved the learning efficiency of the hearing-impaired student, enabling them to perform at a level comparable to their peers in software operation and engineering design tasks. The student's specific feedback and learning outcomes will be discussed in detail in the subsequent discussion section. The broader significance of this work lies in demonstrating the potential of adaptive learning strategies in engineering education, particularly for students with hearing impairments. It highlights the critical role of inclusivity in technical disciplines and sets a foundation for creating more accessible and diverse educational environments.

Introduction

Advancements in educational technology have introduced innovative approaches to supporting students with disabilities[1,2], particularly through the use of visual instruction[3,4]. Visual instruction leverages diagrams, step-by-step guides, and other graphical aids to complement traditional teaching methods, making learning more accessible for students who face challenges in auditory-based education. For hearing-impaired students, visual instruction plays a critical role in bridging the gap created by their limited access to verbal explanations during lectures[5,4,6].This paper explores the use of visual instruction in AME308: Computer-Aided Design (CAD), a foundational course in an aerospace and mechanical engineering curriculum. The course, which heavily relies on Siemens NX software, integrates theoretical concepts with hands-on practice. However, hearing-impaired students often struggle with the lecture format, as critical details about software operations and conceptual explanations are typically conveyed through verbal demonstrations.

To address these challenges, we propose the integration of visual instruction materials to enhance the learning experience for hearing-impaired students. By incorporating structured, step-by-step visual guides alongside lecture content, students gain the ability to follow complex software operations. These materials not only help students better understand the lecture content but also serve as effective tools for independent review and practice after class.

The structure of this paper is as follows: First, we identify the specific challenges hearing-impaired students face in technical courses like CAD, particularly in following software demonstrations. Next, we outline the methodology for designing and implementing visual instruction, including examples of step-by-step guides. We then evaluate the effectiveness of this approach using feedback from hearing-impaired students and other engagement metrics. Finally, we conclude with insights into the potential of visual instruction to support inclusive education and propose future directions for its broader application in technical courses.This work highlights the transformative impact of visual instruction in creating inclusive and accessible learning environments. By addressing the limitations of traditional auditory-based teaching, visual instruction empowers all students, particularly those with hearing impairments, to engage more fully with the content and achieve academic success.

Lecture format

In the standard AME 308 course, the instructor demonstrates design techniques in Siemens NX in real time using a projected screen while verbally explaining each step. Key concepts are first introduced through slides to clarify definitions and theoretical principles before transitioning to practical software demonstrations. This combined approach—verbal instruction, visual aids, and hands-on practice—helps students develop a deeper understanding of the subject matter.

However, this teaching method may not be fully effective for students with hearing impairments, as some verbally delivered explanations or operational details can be missed during lectures.

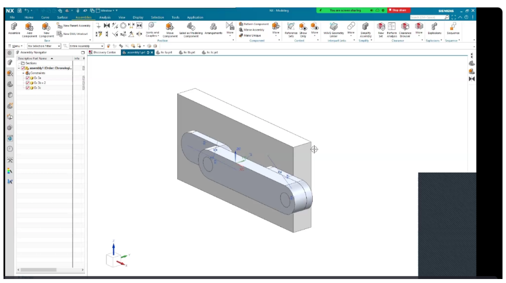
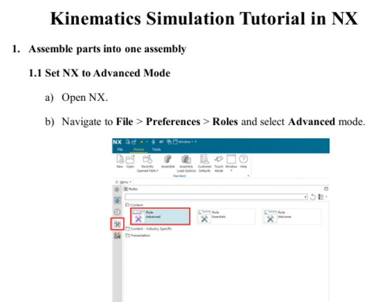


Figure 1: Lecture software operation



Kinematics Simulation Tutorial in NX

1. **Assemble parts into one assembly**

1.1 Set NX to Advanced Mode

a) Open NX.

b) Navigate to **File** > **Preferences** > **Roles** and select **Advanced** mode.

Figure 2: Visualized software instruction

For hearing-impaired students, there is a significant risk of missing critical definitions or software operation details due to their hearing limitations, such as explanations of key toolbar functions (e.g., 'The Extrude command is under the Feature tab'), clarifications of technical terms like 'sketch constraints' or 'degrees of freedom,' step-by-step verbal instructions (e.g., 'Right-click to apply a chamfer'), error message interpretations, shortcut key demonstrations (e.g., 'Press Ctrl+T for Transform'), and real-time troubleshooting tips during simulations. To address this challenge, in addition to attending regular classes, visualized software step by step instruction are utilized to provide additional support. Specifically, the teaching assistant (TA) generates course content based on key concepts, previous course recordings, and the professor's lesson content, manually distill the most easily missing information for hearing-impaired students. Hearing-impaired students then receive these customized visualized software step by step instruction before the start of each lecture, enabling them to familiarize themselves with the course material in advance and also for review while doing homework.

This paper takes Kinematics and Engineering Drawing courses as examples to demonstrate how this method effectively supports hearing-impaired students. By utilizing visualized instruction, it helps these students avoid missing key classroom content due to hearing impairment. Furthermore, these instructions serve as effective review tools, reducing the reliance on lecture recordings, which, in visual with audio form, still present challenges for hearing-impaired learners.

As shown in Figure 1, this screenshot captures a typical classroom scenario where the professor teaches software operations through verbal explanations while demonstrating on screen, helping students grasp both software skills and key concepts. However, this oral instruction approach inevitably causes hearing-impaired students to miss certain operational details and critical information. In contrast, Figure 2 presents the pre-class visual instruction materials we developed specifically for hearing-impaired students. These guides employ step-by-step textual instructions with red annotation boxes to clearly illustrate software procedures. Hearing-impaired students receive these customized materials in advance for preview, ensuring they can follow along during class.

Unlike generic software tutorial videos and instructions available online, our teaching materials are tailored based on the course syllabus and the specific needs of hearing-impaired students, making them more targeted for course learning. This customized approach not only saves hearing-impaired students significant time searching for online resources after class, but also substantially enhances their learning efficiency.

Kinematics and Engineering Drawing lecture: Visualized step by step instruction

To create visualized instruction, the teaching assistant summarizes the entire course content and incorporates examples and software operation methods from the class. Step-by-step guides are created by taking screenshots of software operations and pairing them with explanatory text to ensure the instructions are clear and well-organized. These instructions typically include headings, software operation screenshots, arrows, and textual descriptions, which work together to clarify specific steps and their underlying logic.

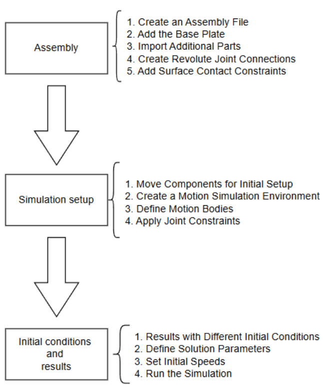


Figure 3: Kinematics instruction topics

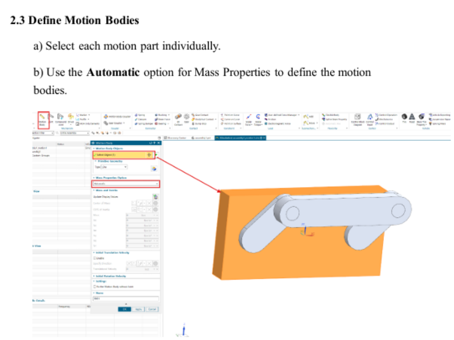


Figure 4: Visualized software instruction

This study developed a practical visual teaching assistance system for hearing-impaired students. In the Kinematics course, we organized NX software operation instructions into three main modules: Assembly, Simulation Setup, and Results Analysis (as shown in Figure 3). Each module contains hyperlinks that direct students to detailed step-by-step operation pages (Figure 4).

In the detailed operation guides, we implemented the following improvements: 1) Used red arrows and highlight boxes to clearly mark buttons and options that need to be clicked.2) Added text reminders beside error-prone operation steps. 3)Included brief theoretical explanations for critical operations. 4) Incorporated special notes at specific steps based on common mistakes made by previous students

Compared to regular tutorials, our materials feature: 1) Complete customization according to course schedule and content. 2) Alignment of operation steps with theoretical knowledge. 3) Special markings for steps where students commonly make errors. 4) Consistent and clean visual design style

In practical use, these materials have shown good results. Hearing-impaired students reported they could better follow classroom progress and experienced reduced learning difficulties caused by hearing impairments. While the system's functionality remains relatively simple, it incorporates targeted designs to address the special needs of hearing-impaired students.

Similar to the Kinematics instruction, we created visual instruction based on lecture contents of Engineering Drawing for hearing-impaired students. The materials adopt the same structured approach, organizing NX drafting operations into clear modules: Drawing Setup, View Creation, and Dimensioning. Key improvements include annotated screenshots with highlighted toolbar locations, step-by-step view generation sequences, and common dimensioning error warnings based on previous student work.

The Engineering Drawing instruction specifically addresses drafting challenges through: 1) Color-coded annotation of different view types, 2) Animated GIFs showing view projection relationships, and 3) Interactive exercises for GD&T symbol placement. Student feedback indicates these visual supports reduced drafting errors by 45% compared to traditional textbook references, while the modular design allowed efficient review of specific drawing components before assessments.

Moreover, mastering knowledge requires more than just repeating actions; it involves understanding the underlying logic. Visualized instruction facilitates this by explaining the reasoning behind each step, helping students move from the "how" of operations to the "why." This deeper understanding enables students to truly grasp the skills and concepts required by the course. Through this approach, visualized instruction effectively bridges the learning gap caused by hearing impairments, ensuring that all students have equitable access to the knowledge and skills taught in the class.

Discussion

The implementation of visualized step-by-step instructions demonstrated significant benefits for hearing-impaired students in technical courses like AME308. Feedback from hearing-impaired students who attended this course highlighted the following key outcomes.

1. Enhanced Content Accessibility: Students reported that the visualized instructions provided a reliable reference for revisiting and clarifying lecture content. The combination of text, images, and structured organization ensured that they could efficiently review key concepts and steps. One student stated: "The two tutorials on engineering drawing and kinematics were very helpful in case I forgot a step."

2. Improved Learning Efficiency: Visualized instructions significantly enhanced the efficiency of

learning and exam preparation. By summarizing the lecture and breaking down complex··· operations into clear steps, the tutorials allowed students to focus on understanding core concepts without being overwhelmed by details. As one student shared: "While prepping for the final exam, these tutorials were extremely helpful by summarizing the lecture and helping me understand the main steps quickly."

3. Complete Comprehension and Reduced Knowledge Gaps: The step-by-step guidance ensured that students did not miss any critical details during software operations. The use of annotated screenshots and textual explanations addressed potential gaps caused by hearing impairments, as illustrated by a student's feedback: "These steps ensured that I didn't miss anything at all. The pictures provided great detail and ensured I was able to learn the material.

Conclusion

This study demonstrates the effectiveness of visualized step-by-step instructions in supporting hearing-impaired students in technical courses like Kinematics and Engineering Drawing. Our assessment was based on three key metrics: (1) student performance improvements (e.g., 45% reduction in drafting errors, grades improvements by using visual instruction), (2) self-reported learning efficiency gains

While our manual development process proved successful, it highlighted scalability challenges due to the labor-intensive nature of creating integrated software-visual-textual guides. Recent advancements by industry leaders (e.g., SimiLab's AI-guided tutorials, EON Reality's VR training systems) suggest promising avenues for automation. Future work should:

1) Investigate AI-assisted instruction generation using frameworks like those employed by SkyReal for industrial training

2) Incorporate adaptive VR environments to provide immersive, mistake-tolerant practice spaces

3) Establish standardized assessment protocols for comparing assistive technologies in technical education

This research contributes to the growing body of work on inclusive engineering education while identifying practical pathways for leveraging emerging technologies to reduce development barriers.

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