A Comparative Study: Using Immersive VR vs. Non-Immersive VR for Design Decision Making in Additive Manufacturing

PennState
College of Engineering

John Ostrander, Snehal Dhengre, Lauren Ryan
Engineering Design and Industrial Engineering
The Pennsylvania State University

Motivation

Additive Manufacturing (AM) is a rapidly growing industry because of its many advantages, but constraints in AM still exist which have an impact on manufactured parts. The following explores whether using immersive or non-immersive Virtual Reality (VR) benefits designers in evaluating parts for AM. This experiment looks at VR environment effect on Design for Additive Manufacturing (DfAM) scoring, decision making times, and DfAM self-efficacy. The following research questions are addressed:

- **RQ1: Is there a difference between Immersive VR and Non-Immersive VR in DfAM scoring? Do varying degrees of design complexity play a role?**
- **RQ2: Is there a difference between Immersive VR and Non-Immersive VR in the time it takes participants to make DfAM decisions? Do varying degrees of design complexity play a role?**
- **RQ3: Is there a difference between Immersive VR and Non-Immersive VR in terms of self-efficacy and other self-reported metrics for DfAM?**

Experimental Design

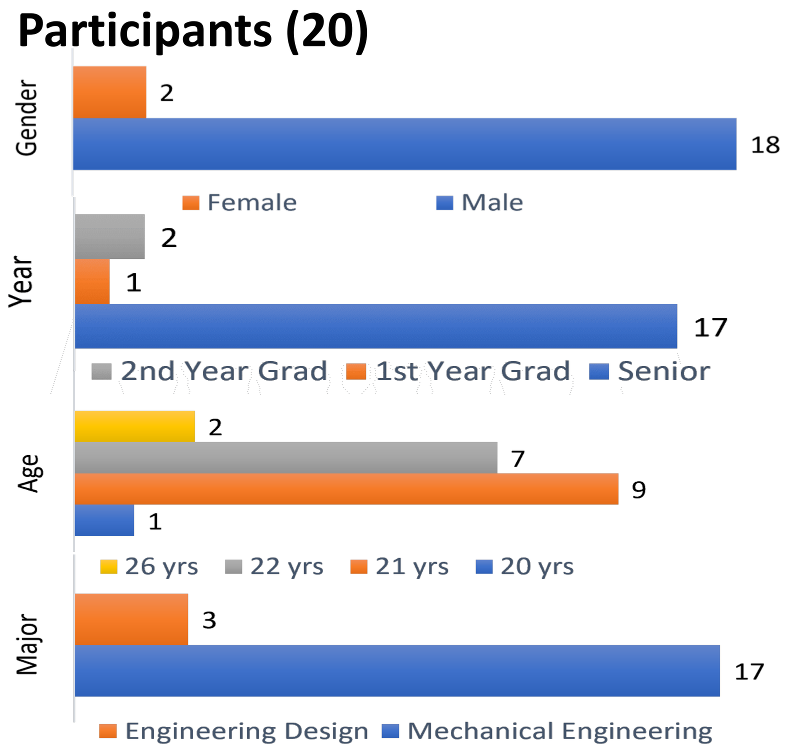
Independent Variables

- **Environment:** Immersive VR (Head Mounted Display-HTC VIVE), Non-Immersive VR (Computer Aided Design-SolidWorks)
- **Part Complexity**: Levels 1 - 5

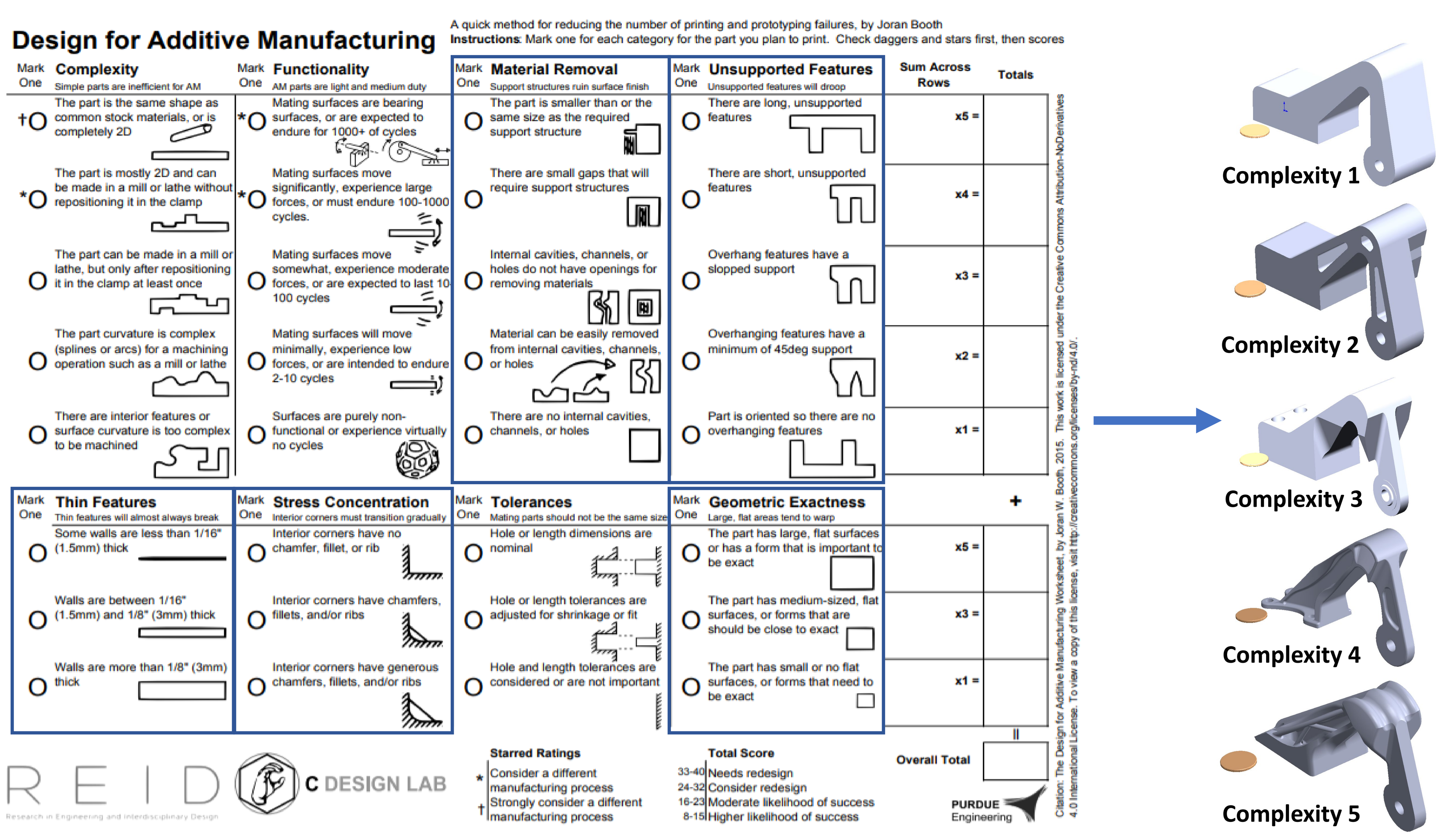
Dependent Variables

- **DfAM Score:** Total score for each part; sum of material removal, unsupported features, thin features, stress concentrations and geometric exactness scores
- **Time to evaluate part**
- **Pre and post self-efficacy scores**

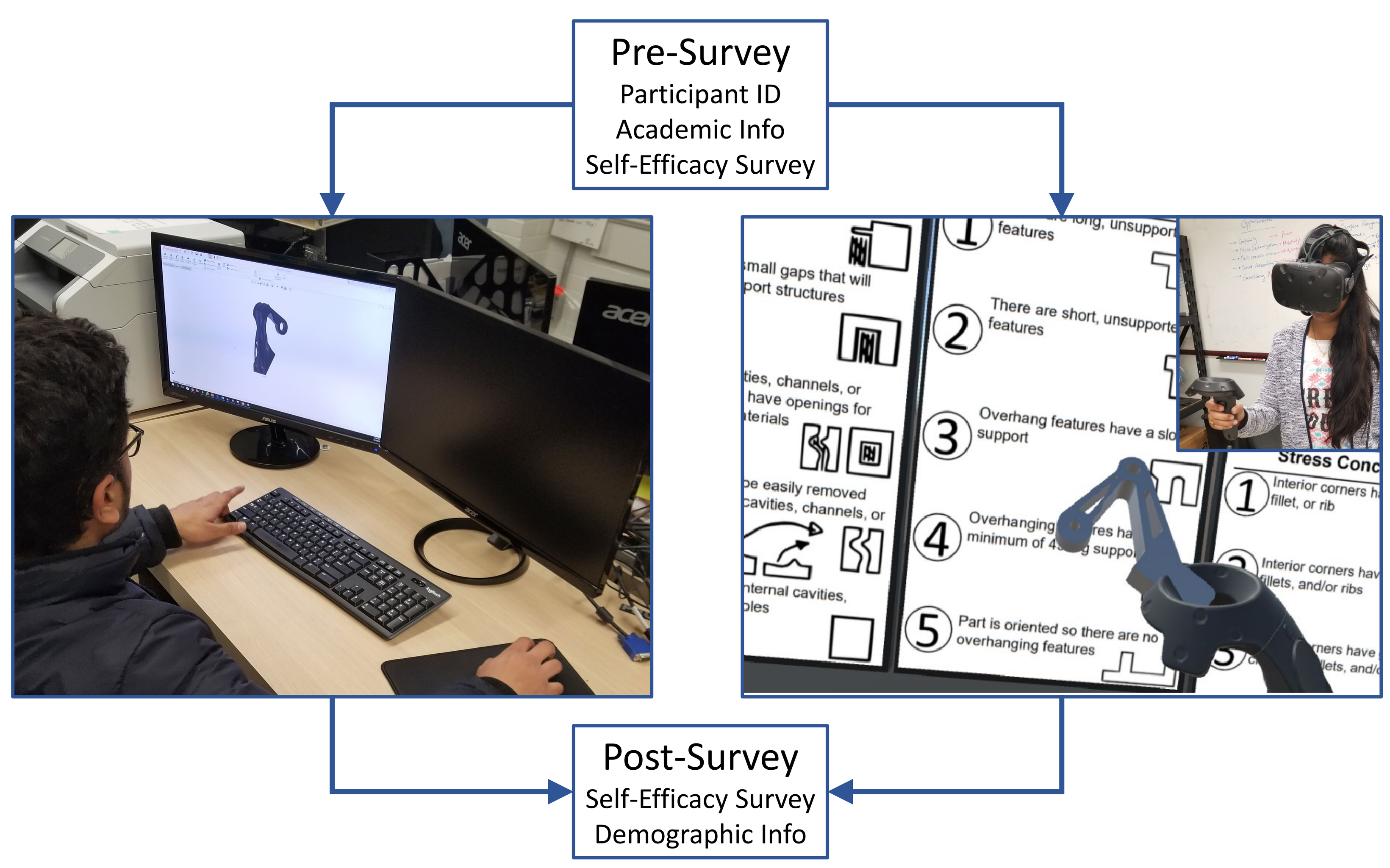
Participants (20)



Design for Additive Manufacturing Worksheet



Experiment Flow

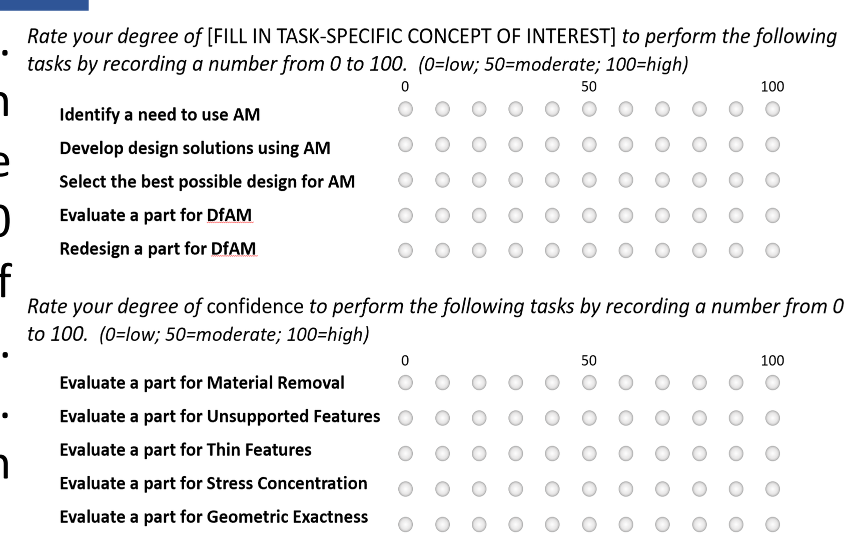


Methods

Each participant took a pre-survey before being sorted into the immersive or non-immersive VR group. Participants scored five different parts taken from an Alcoa Bracket Grab CAD challenge using the restrictive aspects of the DfAM worksheet (boxed in blue): Material Removal, Unsupported Features, Thin Features, Stress Concentration, and Geometric Exactness. Each part was a different level of complexity as defined in the DfAM worksheet (shown left). The time to score each part was recorded as each participant completed the tasks. They then finished with a post-survey. Both surveys included a self-efficacy survey.

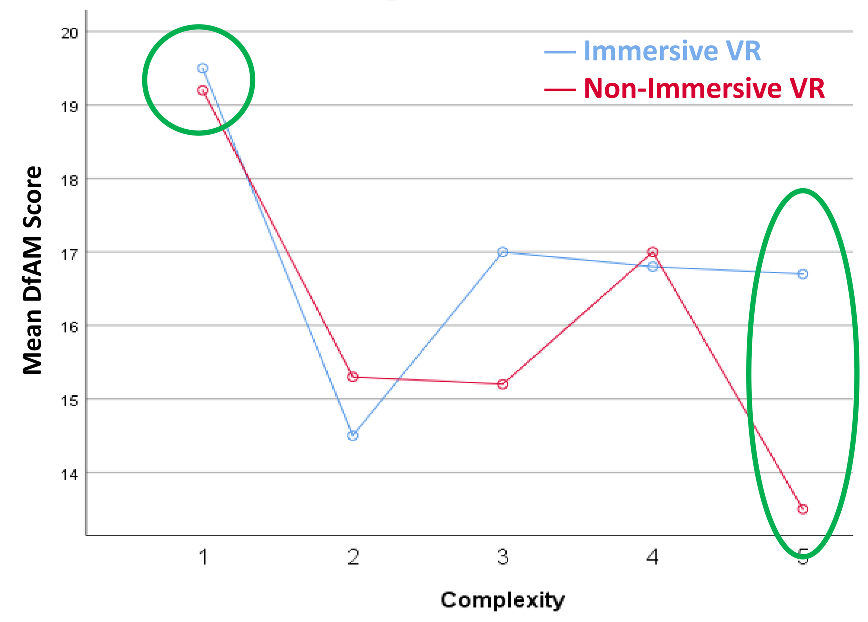
Self-Efficacy Survey

The self-efficacy survey was split into two parts. The first part of the survey listed general design steps related to AM as shown to the right. The participants were asked to rate each step from 0 to 100 for confidence, motivation, expectancy of success, and anxiety in completing these tasks. The second part listed experiment-specific tasks. The participants were asked to rate each task from 0 to 100 for confidence in completing these tasks.

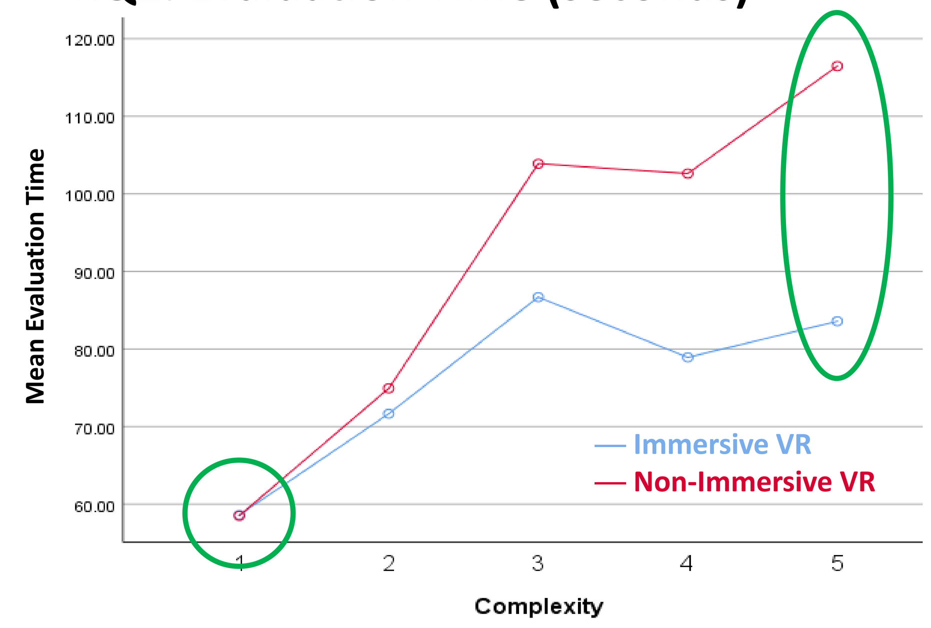


Results

RQ1: DfAM Scoring



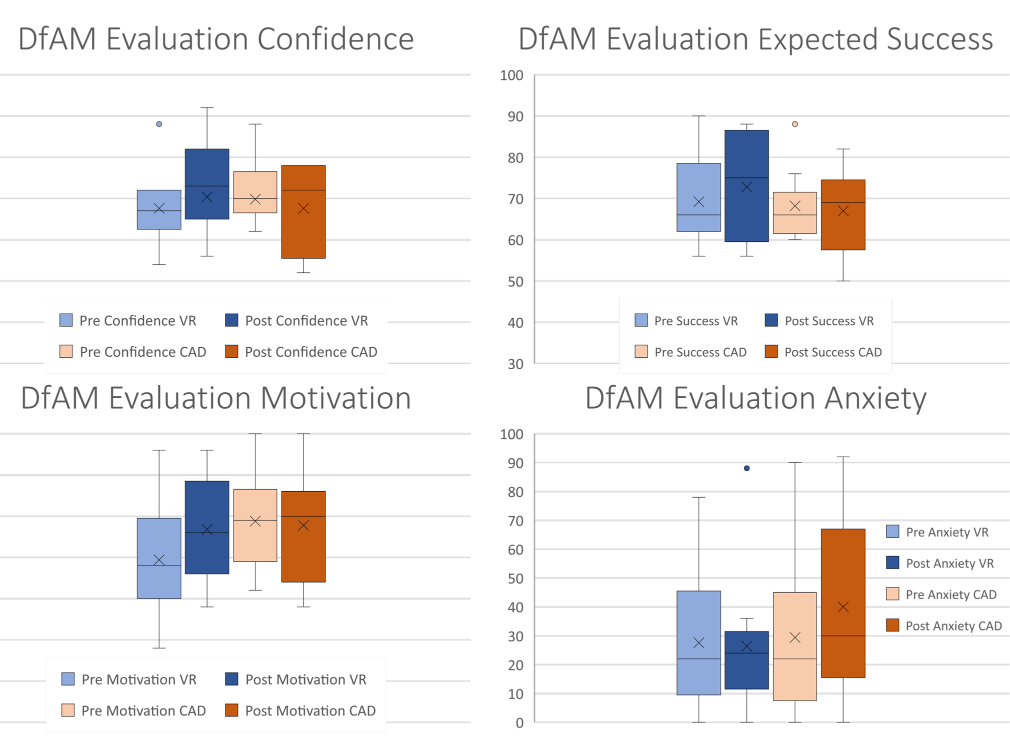
RQ2: Evaluation Time (seconds)



RQ1: As complexity increases, the average DfAM score decreases. For the most complex object, the immersive VR group had significantly higher scores than the non-immersive VR group. A higher DfAM score means higher likelihood of success.

RQ2: As complexity increases, the average part evaluation time also increases. For the most complex object, the immersive VR group had significantly lower times than the non-immersive VR group; more complex objects are evaluated faster in comparison.

RQ3: DfAM Self-Efficacy and Other Metrics



RQ3: No significance was found. Immersive VR had a slightly larger increase in anticipated success. Non-Immersive VR had a slightly larger increase in anxiety.

Future Work

More in depth examination of potential ordering and comparison effects, the comparison of participant DfAM scores to scores given by DfAM professionals, and additional tests with self efficacy data to uncover any significance. Future changes to the experiment include modifications such as noting print orientations, recording "thinking out-loud" of participants, and restructuring the orientation task.

Acknowledgement

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References

[1] Booth, Joran W., et al. "The Design for Additive Manufacturing Worksheet." Volume 7: 28th International Conference on Design Theory and Methodology, 2016, doi:10.1115/detc2016-60407.

[2] Carberry, Adam R., Hee-Sun Lee, and Matthew W. Ohland. "Measuring Engineering Design Self-Efficacy." Journal of Engineering Education, vol. 99, no. 1, 2010, pp. 71-79. ProQuest, http://ezaccess.libraries.psu.edu/login?url=https://search-proquest-com.ezaccess.libraries.psu.edu/docview/217951266?accountid=13158.