Student Synthesis of Complex, Virtual Design Artifacts: What Factors Make a Difference?

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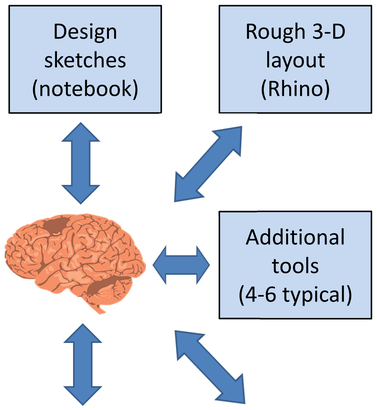
What is the problem?

Unlike more common design-build-test capstone design projects, naval architecture students do not have recourse to a complete physical prototype to help them understand design interactions and visualize the complete design artifact. This vessel synthesis problem is a type of "physically large and complex" system design, as defined by Andrews (2012). The students must synthesize the vessel in their own mind from pieces in different software or formats. This process is a challenge to the students. It relies on a mix of curricular and extra-curricular skills that have not been subject to detailed experimental investigation.



Students must synthesize many analysis methods and data source to create a mental design model - how do they do this?

Investigative Design

The objective of this project is to identify factors which influence this mental synthesis model formation and the trial new learning methods to support its formation.

April 2014
- **Identify major factors and initial teaching responses**
- Initial web-based survey of senior students
- 3 focus groups with senior students

Summer-Fall 2014
- **Plan for 2015 course**
- Design detailed data collection for 2015 class
- Design initial teaching responses

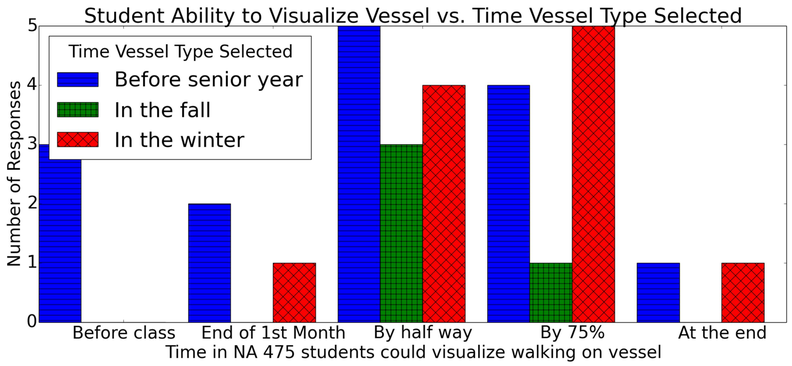
Winter 2015 Class
- **Trial new methods and collect more data**
- Bi-weekly web journals from students
- Trial implementation of new teaching methods

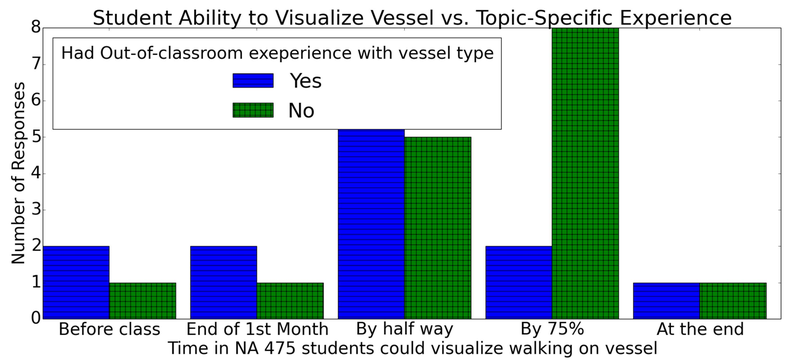
Spring-Summer 2015
- **Final data processing and report**
- Study detailed responses
- Finalize future course improvements

Initial Results

Students could not articulate how they approached synthesis
Despite several prompts of different types in the focus groups, none of the student groups could articulate how they approached the synthesis problem, however they could articulate how they approached the supporting analysis calculations.

Prior interest and specific extracurricular experience were the most dominant factors for explaining which groups had more rapid synthesis
The ability to visualize walking around the vessel was used as indicator of advanced synthesis and investigated against several potential explanatory factors. The total number of internships, and the use of 3-D modeling were not as strongly correlated with the ability to visualize the design.





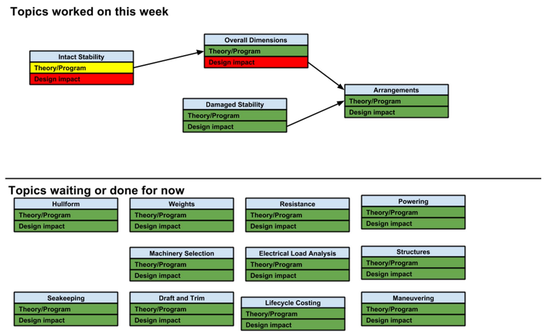
The use of 3-D modeling has become very common but its role in the design process needs further attention owing to its high time demands

3-D Model Type	% Students Using
Displacement and centers calculation	97%
Overall design visualization	90%
Initial internal subdivision and layout	57%

While 73% of students reported the time invested in 3-D modeling was worthwhile, 53% reported spending days or weeks on 3-D geometry conversion problems.

Initial Course Modifications

A design process graph was created to emphasize design process vs. individual analysis tools
- Google Drawing– editable by all
- Students color code topics by impact and their understanding
- Edges in graph indicated design influence



3-D printing was used to create scale models to aid in visualization and synthesis understanding
- Structural design integration identified as an area of particular confusion
- Tangible representation of complex object for those without first-hand real-world experience
- 3-D printing of simplified digital models is a low-cost strategy for touchable teaching aid

Second Stage Data Collection in 2015

Approximately 20 students are completing bi-weekly design journal to give more detailed and time-bound information on the role of:
- Extracurricular learnings
- Use of 3-D computer modeling
- Group communication

Additionally, correlation between self-reported synthesis factors and course grades in 2014 and 2015 are being investigated

Acknowledgements & References

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Andrews, D. J. 2012. "Art and Science in the Design of Physically Large and Complex Systems." *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Science* 468 (2139): 891–912. doi:10.1098/rspa.2011.0590.