Comparing Misconceptions in Fluid Mechanics Using Interview Analysis Pre and Post Hands-on Learning Module Treatment

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Implementation of hands-on pedagogies in the sciences and engineering is usually assessed during and immediately after implementation while studies investigating the effect of treatments on long-term retention of concepts are scarce. This work aims to discover the long-term retention of fluid mechanics concepts using a treatment that employs desktop learning modules (DLMs) with cartridges for a venturi meter and for energy losses in a straight pipe and 180° bend. Interviews 4-6 months after students took the fluid mechanics course offer insight into metacognitive processes and conceptual retention from the course. Questions in the interviews are those developed as part of a previous study investigating persistence of conceptual difficulties for students who have already had a fluid mechanics course. When we compare the two sets of interviews we anticipate results will show greater metacognitive skills and retention in understanding of fluid mechanics concepts for students that had the DLM treatment.

Introduction

Hands-on active learning has taken several forms over the past decades, with the spectrum of hands-on active learning ranging from tasks as simple as students briefly discussing their ideas on a given topic to courses structured around case studies and group work where students are constantly engaging and learning from each other. Implementing the use of alternative pedagogies in the classroom aims to better equip students with critical thinking skills, independence, and problem solving capabilities. Different pedagogical approaches that incorporate active learning include demonstration mode pedagogy, case studies, problem-based learning (PBL), and group work.

To assess the efficacy of these varying pedagogies, strategies include both measuring student attitudes and conceptual understanding at the end of using pedagogy. Yadav’s implementation of case studies in mechanical engineering showed no conceptual difference but student preference for the case study. Dixon, et al used active learning to promote teamwork and professional skills with positive student attitude and outcomes. Lee and colleagues used a computer simulator and showed it helped student to learn and retain deeper engineering concepts.

While these assessment strategies are all positive, engineering education still lacks studies that show how active learning affects students long term. Additionally, comparison studies where one cohort of students does not receive active learning compared to another that does receive active learning are mostly assessed immediately upon the end of the course. Brown, et al. and Abdul et al. both used modular equipment in civil and chemical engineering courses and successfully found positive conceptual outcomes on immediate student understanding. Studies that further investigate conceptual retention after taking courses and with identification of misconceptions, however, are rare.

Determining the longitudinal effect of how hands-on active learning affects student understanding after taking the course is imperative to assess the schema that students develop while experiencing the pedagogy. Schema are developed and function as types of roadmaps for
students to connect ideas and integrate course content. They are mental models – structures – that store and allow recall of information and processes. Students who are forming schema may absorb information but not integrate it correctly. For example, when young children learn that the earth is round but their experience is with a flat earth their mental model structures the earth like a pancake rather than a sphere. This understanding incorporates the relevant information but integrates it into an incorrect mental model. Insuring students absorb and create correct mental models with both theoretical and experiential information is critical to an engineer’s success.

To assist in identification of the cognitive level involved in each question, we used Bloom’s taxonomy. Bloom’s was developed as an educational taxonomy designed to differentiate the complexity of questions for application in educational research. Since published in 1956 with six levels the taxonomy has been extended and applied to several disciplines. The initial conceptualization of the taxonomy included categorization using nouns; in the revised taxonomy these have been changed to verbs with rank order as: remember, understand, apply, analyze, evaluate and create.

In this study, we aim to investigate the long-term affect of hands-on active learning pedagogy and compare it with traditional lecture pedagogy by comparing interview results from fluid mechanics and heat transfer course over a time interval of two years. Students from each year were interviewed using the same interview protocol and each question on the protocol was categorized according to Bloom’s taxonomy. Bloom’s allows the questions to be differentiated based on conceptual difficulty and can offer insight into which levels hands-on active learning are best helping students retain information long term.

The research questions used in this study are:

1. How does hands-on learning affect long-term memory of fluid mechanics concepts?
2. Does the hands-on active learning pedagogy offer better long-term conceptual understanding than traditional lecture pedagogy?

Methods

To assess student’s mental models and determine where their processing may be incorrect, information regarding their problem solving techniques is essential. To measure this facet, interviews with students where they are asked to describe their thoughts while processing through problems are needed. To measure long-term retention of fluid mechanics principles, the interviews are conducted 4-6 months after completing the course. Assessing these mental models will help offer insight to where student incorrectly incorporate information into their schema, and communicate the concepts that students fail to integrate into their schema.

The curriculum at the institution is structured such that junior level (third year) students take the fluid mechanics and heat transfer course in the spring, and the follow fall enroll in a unit operations laboratory. This factor may or may not have influences student’s interview results from the study, but it was consistent for both the group that received hands

In addition to understanding how schemas are affected, this two-year study also aims to follow up on a previous study that conducted interviews of students who had previously taken a fluid mechanics and heat transfer course. This study assessed the persisting conceptual difficulties students held after the course that had demonstration-mode pedagogy. The 2013 course
implemented a hands-on active learning pedagogy using modular technology. Comparison of student answers between the courses allows insight into how the hands-on active learning changed student’s cognitive processes and conceptual understanding.

The interviews conducted for this study were on a third-year (junior) fluid mechanics and heat transfer course. Students were broken into eight teams that equalized GPA and gender for use of the desktop learning modules (DLMs) and accompanying interchangeable cartridges. The DLMs are in conjunction with a 15-year effort to bring hands-on learning into the chemical engineering classroom. The base units are designed with flow meters and pressure readouts with interchangeable cartridges that represent fluid mechanics and heat transfer principles. This study uses a venturi meter and an energy loss through bends and pipes cartridge with a 180° bend. Four of the eight groups received hands-on active learning using the DLMs for the venturi meter and the remainder received traditional lecture pedagogy. The four groups who received lecture for the venturi used the energy loss through bends and pipes cartridge while the other four groups receiving lecture.

This study consisted of 6 semi-structured interviews with students, 3 of which had hands-on DLM pedagogy for the venturi meter and 3 of which had the energy loss through bends and pipes cartridge. The DLM class sessions were intentionally structured around the findings from the interviews conducted on students from 2012, whose aim was to determine the persisting conceptual difficulties students still possessed upon completion of the course. The worksheets used to accompany the DLMs were structured around the findings from the previous course, which indicated students had the most difficulty with the mechanical energy balance, especially applying it in different contexts.

It is important to note the curriculum at the institution is structured such that junior level (third year) students take the fluid mechanics and heat transfer course in the spring, and the following fall enroll in a unit operations laboratory. This factor may or may not have influences student’s interview results from the study, but it was consistent for both the group that received hands-on and the group that received lecture, so it is assumed the two groups are equal with respect to additional hands-on learning.

The interview protocol was updated to better reflect the course content that was covered in 2013. One question from the 2012 protocol was omitted on applying the ME balance to a piping system and another question on continuity was added. The results from the continuity question will be reported elsewhere. The 2013 interview protocol can be viewed in the appendix of this paper with questions emphasizing different usages of the ME balance and understanding of pressure losses through different piping systems. These questions were paired with the two DLM cartridges and relevant concepts to target the effect of the hands-on active learning on long-term understanding.

The recorded interviews were transcribed and coded based on the analysis scheme developed from the previous study. Answers were coded correct or incorrect, coded with concepts mentioned by either the interviewee or included in the question, and if incorrect coded to indicate where the student possessed incorrect conceptual understanding. A comparative analysis based on Bloom’s taxonomy was then conducted with the interview results from 2012, offering insight into the effect of hands-on active learning with DLMs to student long-term conceptual understanding.
Results

The results from the comparison using the revised Bloom’s taxonomy hierarchy can be viewed in Figure 1. 2012 represents the year without the use of DLMs in the classroom, and 2013 represents the years with the DLMs in the classroom. Based on the quantitative results, the students who received the DLM experience had a higher percent of correct answers in every category than those students without a DLM experience. The category with the largest spread between the DLM and non-DLM students is analyze which includes cognitive processes like differentiating, organizing, and attributing information.10

Because the sample size for 2012 was 8 students and the sample size for 2013 was 6 students, sound statistical analysis cannot be performed because the numbers do not constitute a population. However, the aim of this study is to instead compare the cognitive processes between groups, and interview answers from students that offer insight into their mental models can assist in determining the effect of DLMs on forming schema in undergraduate students.

![Figure 1: Comparison of 2012 and 2013 interview results based on Bloom’s taxonomy.](image)

Important student interview responses have been previously published in the analysis from 2012, with student responses to the same questions in the interview noted below. The goal is to compare cognitive processed and development of mental models between students with comparative GPAs.

The first comparison comes from students with a GPA ranging from 2.5 – 3.0 (on a 4.0 scale). The question of interest falls in the create category – students are asked to draw the pressure and velocity graphs as a function of distance in the venturi meter, questions 3B and 3C on the
interview protocol. The student from 2012 changed her answer to question 302 after initially indicating both pressure and velocity increased through the meter.

“Don’t know if that’s a trick question. I mean I guess it’s not a trick question, but... I’m wondering now if I was wrong before, because it seems to me that there shouldn’t be any difference in energy between the two of them, so possible going back to my assumption that both increase from A to B, one of those could be flipped, and that would be why there’s no energy difference between point A and B.”

This response indicates the student was synthesizing information and connecting her knowledge of the ME balance to the venturi system. The student from 2013, took a different approach to the question, however, initially analyzing the system with a broader understanding:

“Well, in equals out, so since pressure is force times area... anyways, as the diameter of the pipe decreases, you have the same amount of fluid going through, but less diameter for it to travel through, so there’s a higher area for it to travel through, so the numerator is bigger than the denominator, so there’s a greater pressure.”

The key to differentiating between these answers – and an indication that the DLMs help students form stronger mental models and connections between them – is the initial approach to problem solving from each of these students. The student who did not receive the DLM treatment from 2012 realized her mistake after initially giving the wrong answer. The student from 2013 who did receive the DLM experience started with a simple fundamental principle - in equals out – and built the answer from this point. While some details are incorrect which leads to an incorrect conclusion, the problem solving technique taken by the student indicates a more holistic analysis of the problem.

Another concept that was emphasized and used extensively in fluid mechanics is the ME balance. A student from 2012, when asked to describe the ME balance answered:

“Ok it definitely has the pressure drop on top, over the... pressure drop will have the pressure drop over the... volumetric flow rate, volumetric flow rate, also have the friction loss, uh, also have the energy... gosh I can believe I forgot this equation, oh umm maybe also have the, um, shaft work in there. And energy loss from the system, pipe. Ok I don’t remember something else.”

Comparatively, a student from the 2013 session that received the DLM experience and used the ME balance explained:

“...(Mumbles as he writes \( \Delta P = \frac{V_s^2}{2} + pgh + \frac{H(a)}{2} + 4h_{fd} + WA_x \)) I know that overall it’s in minus out. I feel like the x should be like \( V_A - V_B \) ad this should be like \( P_A - P_B \) and there’s like \( h_a \). I feel like I never even memorized this equation.”

Both students indicate uncertainty in their answer, especially with their concluding remarks for this question. Each of these students was in the 3.0 – 3.5 (4.0 scale) and comparing their equations indicates the student with the DLM treatment, while not receiving full credit for his answer, understood the components of the ME balance better than the student without the DLM treatment. Each student included a pressure and friction loss terms, and the student from 2013
also included a potential and kinetic energy term. While remembering the exact mathematical descriptions of these terms is important, that type of cognitive understanding falls on the lower end of Bloom’s taxonomy scale. Differentiating between different types of energy enables one to perform a more holistic and better analysis of the given system: a skill that falls on the upper end of the taxonomy.

Discussion

The results from the comparison of the 2012 and 2013 interview analysis results are both qualitative and quantitative. Bloom’s taxonomy, a tool that allows questions to be broken into conceptual difficulty was used to differentiate between the questions asked, and the qualitative results are a result of aggregating answers between all the 2012 and 2013 interviews. Results show 2013 had a better overall cognitive understanding of the course material.

Of more interest, however, is the metacognitive ability and conceptual frameworks students have developed while in the course. The difference between each respective year can be gleaned from the problem solving approaches and descriptions each of the students take when attempting a problem. Students from 2012 immediately answer the question at hand, and synthesize their answer with respect to their understanding of fluid mechanics only after answering the question. The students from 2013, however, are more apt at describing the fundamentals (correct or incorrect) and then continuing to solve the problem once these relationships are established.

Meticulously solving problems and paying to attention to detail are skills that engineers should possess. Additionally, these problem solving techniques are indications of higher-level cognitive ability as defined by Bloom’s taxonomy. The ability to check and critique one’s own work by understanding and integrating the fundamentals is critical to ensuring a proper analysis of the system and comprehensive solution to the problem. While the students from 2013 may need to study the lower levels of Bloom’s taxonomy to better understand the fundamental relationships in fluid mechanics, their text responses indicate higher-level cognitive thinking than those students from 2012.

To answer the second research question posed in this study, it is important to recognize that the students with the DLMs performed better in quantitative analysis and had a more holistic approach to solving problems. The interview data supports the use of DLMs in the classroom, but further analysis with a higher population is required to make valid statistical claims regarding the implementation of DLMs in the classroom. Considering this analysis shows a better performance from use of the DLMs and an ability by students to problem-solve in a more holistic manner, the recommendation is for DLM use in the future.

Conclusions

This study interviewed six undergraduate students approximately 4-6 months after completing a fluid mechanics and heat transfer course. The interview protocol was used from a previous study conducted from the 2012 fluid mechanics course, asking the same questions and comparing answers from each of the respective years using Bloom’s taxonomy to differentiate the
conceptual difficulty of each question. Quantitative results indicate that students from the 2013 cohort performed better on all levels of Bloom’s taxonomy than those from the 2012 cohort. While those who participated in the hands-on DLM appeared to learn more than those who did not, with averages of 3.2/6 (DLM) and 3.5/8 (non-DLM), these results inform us that a full study with statistical robustness is probably warranted. Students most likely develop better long-term conceptual understanding of fluid mechanics using the DLMs, however our data set does not allow us to state this with certainty quantitatively.

With respect to the quantitative results, student mental models are compared using interview text responses. In comparing answers, the 2013 cohort approaches problem solving in a much more holistic way: identifying fundamentals to the system and drawing conclusions in light of these fundamentals. The 2012 cohort, on the other hand, immediately identifies a solution and then steps back to analyze the effectiveness and validity of that solution. This indicates the use of the DLMs in the classroom helps students effectively problem solve in a more methodological and holistic manner and supports the continued use of DLMs in the classroom.

Acknowledgements

We acknowledge support from the National Science Foundation through CCLI Grants and DUE-1023121. We further acknowledge the staff and students of the Gene & Linda Voiland School of Chemical and Bioengineering for support of the work to build, test, and more importantly implement the DLMs. We gratefully acknowledge the insights gained from our NSF collaborators in the WSU School of Civil & Environmental Engineering, Andrew Easley (MS), and Professors Jennifer Adam and Shane Brown, who paved the way for the interview, assessment, and modified design implementation strategy. Finally, we acknowledge the important design contributions and manufacturing of the DLMs by Gary Held, Machinist in the WSU College of Engineering and Architecture Machine Shop.

References


4 Clark, W.M., D. DiBiasio, and A.G. Dixon, An Integrated, Project-Based, Spiral Curriculum for the First Year of Chemical Engineering. in FIE. 1998. ASEE.


**Appendix**

<table>
<thead>
<tr>
<th>Concept</th>
<th>Questions Asked</th>
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<tbody>
<tr>
<td>Flow Regimes</td>
<td>A) What are the main regimes of flow? &lt;br&gt; B) Can you provide a detailed answer on how they are different? &lt;br&gt; C) Draw a representative section of pipe containing each type of flow and explain the differences. &lt;br&gt; D) How would you predict if flow in a pipe is laminar or turbulent? &lt;br&gt; E) What is the Reynolds number? &lt;br&gt; F) What parameters affect the Reynolds number, and what is the equation? &lt;br&gt; G) What does the Re number represent physically? &lt;br&gt; H) How does this physical representation explain laminar flow? &lt;br&gt; I) How does it explain turbulent flow?</td>
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<tr>
<td>Concepts:</td>
<td></td>
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<tr>
<td>- Laminar and Turbulent Flow</td>
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<tr>
<td>- Convective and Viscous Forces</td>
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<tr>
<td>- Transition in Flow Regime</td>
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<tr>
<td>- Flow Regime Impact on Frictional Energy Losses</td>
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<tr>
<td>Mechanical Energy (ME) Balance</td>
<td>A) Write the general ME balance for pipe flow. &lt;br&gt; Follow-up question if incomplete: Are there any missing terms? &lt;br&gt; B) Could you please explain what each term in the ME balance represents? &lt;br&gt; C) What is the physical reason for why pressure decreases down a horizontal pipe? &lt;br&gt; D) Consider flow in a pipe. Where is shear stress represented in the balance? &lt;br&gt; E) Where does the kinetic energy velocity correction factor come from? &lt;br&gt; F) What are the values for laminar and turbulent flow? &lt;br&gt; G) Why does the velocity decrease for flow streams that are closer to the wall? &lt;br&gt; H) Where is the maximum velocity in laminar flow?</td>
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<tr>
<td>Concepts:</td>
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<tr>
<td>- Friction</td>
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<td>- Shear Stress</td>
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<td>- Kinetic Energy Velocity Correction Factor</td>
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<td>- Laminar and Turbulent Flow</td>
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Venturi Meter

Concepts:
- Energy conservation
- Flow work to kinetic energy transformations
- Conservation of mass/continuity
- Isentropic contraction

A) Please draw a plot of pressure for the diagram.

B) Please draw a plot of velocity for the diagram.

Apply the ME balance to the following pipe segments in the diagram and justify removal of any terms.

C) A $\rightarrow$ B
D) What energy quantities change and in which direction, i.e. increase (positive) or decrease (negative)?
E) What would be the difference in total energy between points A $\rightarrow$ B assuming no frictional losses?
F) Why does velocity change through the throat?
G) For pipe segment A $\rightarrow$ C?
H) Which energy quantities change and in what direction?
I) There are often energy losses in contractions and expansions. Why are these minimal in the Venturi meter?
### Straight Pipes and Bends/Fittings

**Concepts:**
- Frictional losses
- K-value loss coefficients
- Summation of energy losses
- Linearizing loss equations to graphically determine loss coefficients
- Relative size of loss coefficient

<table>
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<tr>
<th>Question</th>
<th>Answer</th>
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<tbody>
<tr>
<td>A) Which pipe has greater pressure loss?</td>
<td><img src="image" alt="Diagram" /> (\Delta P_1) vs. (\Delta P_2)</td>
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<td>B) Using the information given, how would you determine the pressure loss in the 90° elbow?</td>
<td><img src="image" alt="Diagram" /></td>
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### Non Circular Channels

**Concepts**
- Hydraulic Radius
- Equivalent Diameter

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<tr>
<th>Question</th>
<th>Answer</th>
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<tr>
<td>A) How do you calculate the hydraulic radius?</td>
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<td>B) What is the physical meaning of the hydraulic radius?</td>
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<tr>
<td>C) Two piping systems have the same equivalent diameter. One is a circular pipe and the other is an annulus. Describe the physical implications of having the same equivalent diameter.</td>
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