

Activity Name: Hands-on construction and testing of thin film microfluidic devices

1. INTERVENTION:

Using commercial off the shelf parts students assemble and test multiple devices that display key microscale fluid flow phenomena such as diffusive mixing and bubble generation. The devices and activity are not resource intensive (i.e., inexpensive & do not require advanced manufacturing facilities). The technology also enables devices that make foundational microscale phenomena visible to the naked eye. The activity is designed for students who have completed an introductory course in macro scale fluid flow phenomena, and was designed particularly for students enrolled in a class on microfluidics theory and uses. Through hands-on construction of devices students encounter and grapple with latent misunderstandings of micro and macro scale phenomena. Doing so reduces the potential that they may otherwise retain such misconceptions when learning material in the larger class about fluid flow phenomena. The role of the instructor (and activity design) is not to prevent or correct mistakes in device assembly, but rather to support students in reasoning through assembly errors that result from their misunderstandings. The result of the activity is a stronger conceptual understanding of phenomena discussed in the microfluidics course.

WHY

2. THEORY:

The activity is based on work about conceptual learning by Chi and others. Two concepts in educational theory are relevant to this activity. The first is misconceptions – places where mis-organized conceptual understanding negatively impacts future learning. Specifically, work on misconceptions in thermofluids by Streveler and others. Misconceptions provides a theoretical basis for the types of learning that the activity is designed for. The second relevant concept is conceptual change theory (see again, Chi). Conceptual change theory outlines a process by which incorrect prior conceptions must be made visible, interacted with, and then a new (correct) conception created. It specifically differentiates this type of learning from learning about concepts where students have no formal knowledge or organically developed understanding of a topic. Conceptual change is an appropriate theory for creating this activity given (1) the known misconceptions about and students prior training in macro scale phenomena and (2) the resulting high likelihood that existing organizations of that knowledge will malform learning about new micro scale phenomena. We see conceptual change as within a broader umbrella of inquiry based learning approaches which influenced specific aspects of the activity such as the instructor role. (see manuscript section on theory of learning for relevant citations)

3. LEARNING OBJECTIVES:

The specific learning goal(s) that we established for students participating in the activity were:

1. Apply theoretical knowledge about device function to physically construct and test devices
2. Experience, reflect, and refine their individual conceptions of fluid and microfluidic differences
3. Evaluate failure modes from device manufacturing discussed theoretically in class
4. Link fundamental concepts of microfluidics to device's physical function

4. SCIENTIFIC PROCESS CONTENT:

Note: GREET labels this section EBP steps. The EBP steps were developed with patient care and medical education in mind, but translate well the a general scientific process. We describe the general scientific process that students engaged in during the activity here.

Students were provided minimal direction in the correct assembly process of devices, but were not provided information on how to identify proper assembly, function, or address problems with devices. When confronted with uncertainty or problems during the activity, students were required to make observations of their device and working devices, rely on theory or course materials, and other sources. That information could then be used to adjust their process or devices either through or before testing to ensure the devices performed properly. Our results show several times (e.g., the function of bubble generator) where students explicitly identified changes in their understanding through scientific observation and experimentation.

WHAT

5. MATERIALS:

- Materials for construction and testing devices – see full BOM in supplemental materials
- Pre assembled working devices for comparison purposes
- Nitrile or similar basic disposable laboratory gloves

6. EDUCATIONAL STRATEGIES: The activity is similar to a typical simple classroom laboratory experiment. The activity occurs over two to three 50- minute class sessions using the materials described above. During the activity students work in small groups while the facilitator(s) circulate and ask questions and make observations. The activity was used, but does not have to be used, as part of a larger class on microfluidics that used a variety of lecture-based strategies for instruction.

7. INCENTIVES: Students participated in the study as part of their normal enrollment in the overarching graduate course on microfluidics. No incentive was given for consenting to participation in the study. All students participated in the activity as part of the course, and all consented to their data being used in the study.

WHO PROVIDED

8. INSTRUCTORS: For each instructor(s) involved in the educational intervention describe their professional discipline, teaching experience/expertise. Include any specific training related to the educational intervention provided for the instructor(s).

- Instructor 1: Engineering background (mechanical and biomedical engineering), with a PhD in microsystems/sensors and Postdoc experience in biomedical research. Previously have served as teaching assistant for 2 courses. Have designed and implemented new translational microsystems course, and taught for 2 semesters.
- Instructor 2: Graduate student with engineering background (biomedical engineering BS) who has taken courses on transport and microfluidic phenomena. Direct research experience with microfluidics and served as a teaching assistant for 4 courses.

HOW

9. DELIVERY: The activity occurred face to face and was performed with students working in groups of 2-4 students.

WHERE

10. ENVIRONMENT: A classroom with seats and a table for each group (i.e., an ‘active’ or ‘flat’

classroom). The environment should be typical of indoor air conditions. The room should be relatively clean (e.g., ISO 9, room air or better), with the primary concern being particulate or debris inhibiting proper device function. Spaces compliant with appropriate NFPA, IBC, OSHA, and other codes for office spaces or similar general use facilities are sufficient.

WHEN and HOW MUCH

11. SCHEDULE: 2 or 3 sessions of 50 minutes in duration over 1-2 weeks. No specific pre-class preparation before or after this activity was expected of students

PLANNED CHANGES

13. Did the educational intervention require specific adaptation for learners?

We have not encountered or identified any changes that we plan to implement. The activity does require typical adult levels of dexterity and vision. It would likely be helpful to pair students with atypical movement capabilities or uncorrected vision with others to ensure that device assembly is possible. As the activity stands, we unfortunately do not know of any reasonable modifications to support such participants besides grouping them with others.

UNPLANNED CHANGES

14. Was the educational intervention modified during the course of the study? If yes, describe the changes (what, why, when, and how).

Yes, the activity was modified twice. The first modification was to create a shorter version of the activity to test (1) the reliability of student device assembly and (2) whether students at the lower end of our pre-requisite knowledge about fluid phenomena learned differently. The shortened version involved only creating two devices instead of four. The second modification involved extended the activity from 2 to 3 50-minute course sessions to allow participants more time for self-directed experimentation. That change occurred between the first and second uses of the activity in the microfluidics course.

HOW WELL

15. ATTENDANCE: N/A – we did not have a formal attendance policy

16. Describe any processes used to determine whether the materials (item 5) and the educational strategies (item 6) used in the educational intervention were delivered as originally planned. – N/A

17. Describe the extent to which the number of sessions, their frequency, timing and duration for the educational intervention were delivered as scheduled (item 11). – As planned