A Framework to Guide Design of Interactive and Constructive Learning Opportunities

Dr. Tracy Q. Gardner, Colorado School of Mines

Tracy Q. Gardner graduated from the Colorado School of Mines (CSM) with B.S. degrees in chemical engineering and petroleum refining (CEPR) and in mathematical and computer sciences (MCS) in 1996 and with an M.S. degree in CEPR in 1998. She then got her Ph.D. in chemical engineering, studying transport in zeolite membranes, from CU, Boulder, in 2002. She did a postdoc at TUDelft in the Netherlands in 2002 and 2003, studying oxygen conducting mixed oxide membranes and teaching reactor engineering, and she has been teaching back at CSM since 2004. She is now a Teaching Associate Professor in (and was also for 5 years the Assistant Department Head of) the Chemical and Biological Engineering Department at CSM. Her primary research focus is in pedagogy, specifically in utilizing hand-held devices and other technology and different teaching methods to increase student engagement and reduce/eliminate lecturing in the classroom. She likes to play with her kids, play racquetball, run, bike, swim, and play pool in her free time.

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Abstract
To set the stage for this paper, please view the following YouTube video: https://www.youtube.com/watch?v=KdxEAt91D7k (Kid Snippets: "Math Class", by Bored Shorts TV). This is a perfect demonstration of so many things that frustrate both students and professors and also of something my father used to say all the time and that exemplifies why teaching through "professing" or telling students things, *even if you are interacting with them one-on-one as you do it*, doesn't tend to work well:

Catch Phrase #1 – "A person convinced against their will is of the same opinion still"

Active learning beats passive learning when it comes to students understanding concepts and retaining information and skills – that is clear [1]-[11]. Although more and more educators recognize the value of using active learning, how to effectively implement it is less straightforward. How is "effectively" defined in this context? What are appropriate ways to *assess* student learning? What methods work best in which situations and for what kinds of students? As a new professor, how can I get my career going and also put in the time required to teach in the best way possible particularly if that is different than how I have been taught? or As someone who has been teaching in a more traditional lecturing style for years, why should I/how can I change my methods? After 14+ years of university-level teaching, 18 different courses from freshman to graduate-level at my current institution; experimenting with a wide variety of methods, technologies and tools; and as many years participating in conversations, workshops, and seminars on the topic, this professor has amassed a set of tricks, tools, and ideas that may be helpful for addressing these questions of implementation and creating effective interactive learning environments. This paper is meant to help anyone wanting to incorporate "active learning" in their classes by i) providing some checklists of things to *consider* when designing your course, activities and assessments; ii) highlighting some pits one can fall into when working toward "flipping" their class, assessing learning outcomes, etc.; and iii) offering some short catch phrases to help keep one on the path to greater student learning outcomes. Many of the basic premises here have been presented in great detail by other authors previously. Some of these I had heard about before attempting in my own courses and others I had just tried "on my own" and later learned how they fit in with the pedagogical literature. The hope is that having what has worked (and not worked) for one "seasoned" faculty member summarized in succinct checklists with specific examples will help both new and established faculty feel more comfortable implementing interactive and constructive learning opportunities in their classes.

Notice that the word "*consider*" above, in reference to the checklists provided here, is italicized… hence *emphasized.* The catch phrase "a person convinced against their will is of the same opinion still" applies equally well to faculty as to students. The best advice I can give is that you must find your own way – what works for you. Gather ideas, lessons learned, best practice tips, etc., implement one to a few of the best sounding new things when you see a need and feel comfortable doing so, and make your course your own. The ideas presented here are not a prescription that must be followed nor are they even close to a comprehensive set of important ideas for teaching effectiveness. They are simply things that it may be helpful to *consider* when designing your course elements with some anecdotal examples to help illustrate and hopefully make memorable the thoughts presented.

For example…my first semester as a "real" faculty member, I co-taught Material & Energy Balances with a fabulous colleague who had been my own professor when I was an undergraduate. He was one of the best instructors I had ever had; and given the high quality of the faculty at my undergraduate institution, that is saying a lot! I followed his lead and taught that course his way. He was one of those who can use PowerPoint effectively, so he would teach on his days with his presentations and I would teach on my days with mine. It turned out that his way was *not* my way. I felt like a fish out of water teaching with PowerPoint slides, and I was consequently not as effective teaching that way as I could have been teaching another way. It wasn't just that I was relatively new to teaching and was struggling for that reason. I was also teaching Heat Transfer that semester and I did that one on the board with my own handwritten notes, to significantly greater success and happiness for both the students and myself. It also wasn't just that MEB was co-taught with someone else. I have had wonderful experiences co-teaching with other faculty when each faculty member had the flexibility to teach in their own way. I could have done this in my first MEB course, but I chose not to since it seemed easier to use the slides that were already prepared and I knew how good my colleague was at teaching. In the end it would have been a significantly better experience for everyone and probably even saved me time in the long run, had I chosen to teach differently on my days. So to re-emphasize, I suggest anyone looking to either begin to teach or to make changes in their teaching see all others' suggestions, methods, papers, books, etc. as sources of ideas, don't be afraid to try new things, but make sure you feel comfortable personally with the methods you choose to use and make them your own.

Catch Phrase #2 – Start with the End in Mind: Learning Outcomes First! (and Second, Third…and Last)

The ideas for this first tool come from some of the greats in engineering education [3], [4] (and many others) – I simply summarize them here as a checklist to print out and post on your wall as the four commandments to which you should refer continually throughout any course design:

Checklist #1 – Overall Course is Designed for Success

- Course is designed around very well thought out learning outcomes (LO's).
- Every activity directly ties to one or more of those LO's.
- At least formative and possibly also summative assessments of students' attainment of or progress toward those LO's is regularly conducted.
- Adjustments to the course delivery are constantly considered/made based on those assessments.

Fully understanding and getting good at achieving each one of these checklist items may take some time. The first bullet point, for example, has several levels in and of itself. What does "very well thought out" mean? Starting with the end in mind, instructors of a course should first think about what successful students will be able to *do* at the end of the course because of the course. These new skills the students will have should include at least some that are higher-level (create, evaluate, analyze…) and will likely also include some that are lower-level (recall, define, explain…). As an instructor, your first job is to analyze what skills the students must gain in your course in order to be successful – in later courses, as a working scientist or engineer, etc. Then write student-focused learning outcomes that are SMART (originally defined by George Doran as Specific, Measurable, Assignable, Realistic, and Time-Related but slightly re-defined to apply to student learning outcomes). Many courses have learning outcomes that are written either in terms of what the instructor will do or what the course will do or even if they are written in terms of what the student will be able to do they are written in ways that make them difficult to assess.

> <u>Pitfall #1</u> – Learning Outcomes that are either non-existent in a syllabus (as I hate to admit was the case for a couple of courses for me early on!) or poorly written are usually difficult to impossible to assess and are therefore not as helpful either to students or instructors as LO's could and should be.

<u>For example</u>, a learning outcome that students should be able to "understand pump curves and how pumps work in series and in parallel" is not easily measured. How can I tell if the student "understands" a pump curve? A better LO might read students should be able to "Determine the deliverable head given a required flow rate from a pump curve and translate that information into the potential energy increase and/or pressure increase across the pump for a given fluid." And a separate LO might read "Communicate in writing the advantages and disadvantages of using pumps in series vs. in parallel and judge which would be the better configuration for a given pumping requirement." I just made those up in two minutes, and while not perfect they are far better than the original outcome wording that was on my Fluid Mechanics syllabus in 2011. The reason I mention that I just made those up is to encourage those of you who are hesitant or think it is either not worth it or too difficult to write "good" learning outcomes to go ahead and do it! Here is a checklist to help:

<u>Checklist #2 – Learning Outcomes are SMART:</u>

- Specific (and student-centered) – state <u>exactly</u> what the <u>student</u> should be able to <u>do</u> at the end of the course.
- Measurable – see Webb's Depth of Knowledge for a great list of measurable verbs across all levels of thinking skills [5].
- Achievable – requires instructor understanding of course pre-req's, other demands on students during course timeframe, etc. to assess this.
- Relevant – each part of each learning outcome should be necessary for the students to achieve during the course based on what the course leads to (next course(s), certificate, degree, etc.) and set of LO's should provide all of the necessary content and skills for that course.
- Timebound – time constraints for specific tasks and overall attainment of LO's should be considered such that all LO's can be attained and assessed in the course. Time constraints should be specified somewhere, though not necessarily in the LO itself.

Try to limit the number of these course-level learning outcomes to 10 or fewer. An example list from a Heat Transfer course is given here:

Example Course-Level Learning Outcomes

In order to successfully complete CBEN 308, students should be able to:

1. Explain in your own words the three modes of heat transfer: **conduction, convection, radiation**; in terms of each mode's relevant **driving force**, **proportionality constant**, and **area** for heat transfer and for each mode describe a physical situation in which that mode dominates or contributes significantly to the overall heat transfer.
2. Go through the process of solving a **steady state** heat transfer problem. This includes determining the relevant heat transfer mode or modes operating for a given system and set of conditions; interpreting and gathering necessary data on solid and fluid properties; evaluating conduction, convection and radiation heat transfer **fluxes/resistances**; and combining them in the appropriate network to determine overall heat transfer **rates**.
3. Derive the fundamental conduction equation for a given system from a **microscopic energy balance** on the system.
4. Apply the fundamental conduction equation to a given conductive heat transfer system in **any coordinate system**, identify the **boundary conditions**, and solve **analytically** (1-D, steady state) and numerically (any conditions) for the **temperature profile** in the system.
5. Identify for a given time-dependent system the appropriate **transient** heat conduction equations and apply them to solve for temperature profiles and heat transfer rates in **0-D**, **1-D** and **multidimensional** systems.
6. Select and apply appropriate **convective heat transfer correlations** and use them to calculate heat transfer coefficients for **internal** and **external** flows including **sensible** as well as **latent heats** (temperature and phase changes).
7. **Design heat exchangers** for given performance and **predict performance** for given heat exchanger configuration and area using the LMTD and NTU methods.
8. Evaluate and **communicate in writing** ways to improve heat exchanger performance based on **evaluating controlling resistance**.

Some features to note: The LO's are specific and student-centered – i.e. exactly what the student should be able to do at the end of the course. The important things for students to focus on in each LO are in **bold** to direct the students' attention to them. The verbs are chosen so as to be measureable with well-designed assessments. The LO's include some lower-level and some higher-level thinking skills, all of which are achievable in 1 semester of a 3 credit course. The time-bound nature of the LO's was considered as they were set and comes through in how they are spaced throughout the course and in how they are assessed. The learning outcomes are relevant – i.e. only the topics the instructor thinks are important for this course are included. There are many interesting topics in Heat Transfer and even in the text this instructor uses that are not included here. This brings us to our second pitfall of which to be aware…

> Pitfall #2 – Following a text too closely and/or taking time in a course for interesting but not necessary topics, or worse yet for ones that are not even interesting, is a waste of both the students' and the instructor's time.

For example, an interesting phenomenon arises when one is insulating cylindrical or spherical geometries: as the insulation thickness increases the conductive resistance to heat transfer through the insulation increases, tending to decrease heat transfer (as one would expect of insulation). However, the outer radius of the insulation also increases with thickness, which conversely *decreases* the convective resistance at the outer surface, which would tend to increase heat transfer. There is a "critical radius of insulation" below which adding insulation increases the heat transfer rate! This is a counter-intuitive and kind of cool concept, but when one considers what Chemical Engineers typically insulate – i.e. pipes in a chemical plant with low thermal conductivity insulating materials, that critical radius is on the order of 5 cm or less, which is less than the radius of most pipes even before the insulation is added. Hence this isn't really an issue of concern for most Chemical Engineers. For electrical engineers on the other hand, who might "insulate" wires (small radius) with plastic coatings, this phenomenon might occur and actually be advantageous as it could increase the heat transfer rate and keep the wires cooler. Therefore this topic might be considered as one that is interesting but not necessary in a Chemical Engineering Heat Transfer course, and could be included *if* time allows.

To be clear, this doesn't mean that one should strip down any course to just the basics. Quite to the contrary! The goal is to hopefully get to more depth – i.e. more important higher level learning outcomes – and that time can be gained for doing so by narrowing the breadth and focusing on the most important content. Using the critical radius of insulation example to illustrate this idea, the "Aha! moment" students can gain when recognizing that both the area for heat transfer and the insulation thickness affect the resistance and in opposite directions for radial geometries may be a useful one for honing critical thinking skills and perhaps for design-related objectives. In that case, one might decide to keep the topic in the course but then it could be tied to a higher order learning outcome that captures that critical thinking/design element.

So in summary, don't just follow exactly along with a text, if you use one. Decide first what content really needs to be in the course and what skills and knowledge the students need to be able to demonstrate they've gained based on what the students need at the end of it, write the learning outcomes to address those needs, and make sure everything in the course ties directly back to a learning outcome. Course-level LO's tend to be broad, overarching outcomes and therefore should be broken down into smaller chunks by writing unit-level learning outcomes and then further into daily learning outcomes. These smaller bite-sized chunks are easier to assess. The checklist below should be used at the beginning of the course as you set your LO's and then reviewed with every element of your course as you design it.

<u>Checklist #3 – All Instructor and Student Activities Tie to Course LO's</u>

- Course LO's are mapped to Module or Unit Level LO's (a typical course might break up into 2-6 modules or units grouping related topics) – Module or Unit Level LO's can form the basis for exam study guides.
- Module or Unit Level LO's are mapped to daily LO's – begin each class stating the day's LO's and wrap up the class by coming back to them.
- Every ___________________ (below) maps back to at least one course-level LO
    - Reading/video/etc. out-of-class assignment
    - "Lecture" topic
    - In-class activity
    - Homework problem
    - Project assignment
    - Quiz question

- Exam question
- __________________ (anything else in the course)

However, keep in mind that ultimately you need to assess the course-level learning outcomes themselves!

> Pitfall #3 – Breaking course-level learning outcomes down into unit-level learning outcomes and further into daily learning outcomes *can* lead you away from actually assessing the higher-order thinking skills written into the course-level LO's! Similarly, assigning only problems tied directly to the most recent "lesson" or writing quizzes that closely resemble the most recent homework likely won't assess higher-level LO's either.

For example, a good learning outcome for a course in Heat Transfer might read: "Select and apply appropriate convective heat transfer correlations and use them to calculate heat transfer coefficients for internal and external flows including sensible as well as latent heats (temperature and phase changes)." This might break down ultimately to a learning outcome for a single day along the lines of "Determine the convective heat transfer coefficient for the shell-side of condensing steam heat exchanger of design X given parameters {Y}." If the day-level learning outcome is assessed by scoring how students do on this specific task immediately after they have read/watched a video on/heard a mini-lecture about how to do this, they are likely to do well. Mapping this daily outcome back to a unit-level outcome which maps back to the course-level outcome, one might conclude that the course-level outcome (or at least the related part of it) is achieved. However, since the students likely just applied a concept they had just learned to solve a specific problem, this is more of a lower-level learning outcome and doesn't actually assess their ability to "select and apply" appropriate correlations. Some guidelines for designing effective assessments are given in Checklist #4.

Checklist #4 – Assessments are Designed and Used for Instructor and Student Success

- Formative assessments occur regularly (1 to several times per week in a typical course); may be graded or not but must inform both instructor and student of student's level of attainment of or progress toward course-level LO's.
- Instructor analyzes formative assessments regularly (at least 3-4 times per course) and directs course based on student performance on formative assessments.
- Each element of each course level learning outcome is assessed *as it is stated* (i.e. not at a lower-level thinking skill way) in at least one and ideally more than one summative assessment.
- Students have had practice at demonstrating each higher-level learning outcome before its final summative assessment.

Returning to the Heat Transfer example above, a final exam problem asking students to design a heat exchanger to use available steam to heat a certain process stream up from T_1 to T_2 within a specified area footprint would assess elements of course level learning outcomes 2, 6 and 7 at least, and one could easily add learning outcome 8 directly as a part b)! On the other hand, asking students to do each individual part of the problem separately – determine the convective heat transfer coefficient for condensing steam under X conditions, calculate the internal convective and conductive and external convective resistances and determine which is controlling, size a heat exchanger to provide X duty under Y conditions, etc. would each likely get at one or more lower-level learning outcome(s) but would miss the higher-level outcomes that the students ideally should achieve. Along with that thought, if students are guided along the way throughout the course and only see the more open-ended or fewer-part questions on the final exam, they have not been adequately prepared for those assessments. Therefore students need practice throughout the course at solving the bigger picture, more open-ended, fewer-part questions that we want to test them on. Formative assessments in the form of in-class activities working on bigger picture problems can provide these opportunities, and peer-to-peer feedback and in-class discussions can allow these opportunities to occur regularly without the instructor having to spend countless hours grading student work. The next section delves into an example of such an in-class activity.

Catch Phrase #3 – In-class time for interaction; out-of-class time for outer-action

Ok, so I made up the term "outer-action"…but hopefully the point is clear. The basic premise of the approach outlined here is that content delivery, in-class activities and out-of-class assignments should be designed such that in-class time is reserved for things best done with interaction (student-student and/or student-learning facilitator) and out-of-class time is for things best done at the student's own pace and/or on their own. One mistake I made when first starting to incorporate "active learning" into my classes in a more formal way was thinking that if the students are talking and working together, then they are being active, and that's good, and that's the end of that. While it is true that students engaging with the material is a necessary component of active learning, it is not a sufficient measure to ensure greater learning outcomes.

> <u>Pitfall #4</u> – Believing you've *effectively* incorporated active learning in your course because your students are gathering content outside of class and are working on problems in class and that that is all it takes to improve student learning outcomes is likely to prove inaccurate.

Active learning is better than passive learning, but there are different types of active learning and some are better than others when it comes to students attaining greater learning outcomes [6], [7]. Chi discusses four separate student engagement behaviors – passive < active < constructive < interactive, with interactive being at the top and leading to the highest learning outcomes [7]. Chi goes into detail better defining the terms and justifying the progression [8]. Taking them more basically though, as many wanting to incorporate active learning might also do, I view constructive and interactive as two parts of a Venn diagram, both subsets of the bigger active learning circle (which is clearly better than the separate passive learning circle), but which each has both separate and overlapping parts within the active learning circle. That is to say, activities in which students construct new knowledge or ideas (to them) from ones they've been introduced to can either be done individually or interactively with others. Similarly, activities in which students interact with one another and/or a learning facilitator can either be constructive or not. My contention is that the overlapping part of this Venn diagram is where the sweet spot most often lies, but that sometimes more learning might occur if students act individually rather than interactively, and some topics might be better learned with interaction even if no new ideas are constructed. Instructors should know both the material and their students well and design out-of-class and in-class activities taking these distinctions into consideration.

Checklist #5 – In-Class and Out-of-Class Activities are Where They Belong

- Most of the "content-delivery" happens outside of class. Students pick up material in different ways and at different paces. Therefore, whether they are expected to *first become exposed to* the new concepts by reading, listening to an instructor, watching videos, playing with simulations, etc. they should be doing this mostly outside of class since it does not require and can be hindered by interaction with others. Exceptions include particularly difficult to understand topics that instructors know typically cannot be grasped by most students without discussion. These topics can be introduced in the classroom as long as discussion is well facilitated.
- When students are in the classroom, they are interacting with each other and/or the instructor most of the time. Ideally there will be periodic interaction between the instructor and the whole class to get everyone started or to the same place after some working time, some interaction between instructor and one to a few students at a time as they work, and a lot of interaction between students.
- In an ideal world, individual summative assessments like quizzes and exams would take place out of class since they are the activities that LEAST require (and typically don't allow for) interaction. This is not always possible though.
- Additional out-of-class time required for "content-delivery" is compensated for by less homework or more homework assistance in class when compared with traditional lecture/homework model. (Not doing this is Pitfall #5.)

Example: Note that the first bullet point suggests that even if students are to be exposed to new material via "listening to an instructor", that should happen outside of class. Recording lectures is one way this could be done, but student attention spans don't tend to be 50 minutes even if they are watching a video. Even 15 minutes is a long time for students to sit and watch a "content delivery" video. I used to teach in class with skeleton notes – handwritten notes on a tablet that I would then highlight the key parts that I thought students would learn more by writing, then I'd post skeletons with those highlighted parts removed. In class I would talk and fill in the skeleton notes on the tablet projected to them while they filled them in. This provided the students with complete notes, motivated students to come to class since the completed notes were never posted, and allowed for more time in class to do problems, discuss concepts, etc. Many students love skeleton notes, but some…do not. So now I make ~3-8 minute screencasts – 4-5 per typical 50 minute lecture time – "delivering the content". These are supplementary to the reading, so those who want them can watch them and those who prefer to read can take that option, and still others do both (or neither – the latter don't usually pass). This is a great way of differentiating learning as it allows students to explore content at varying rates and in varying ways depending on what they need and on how they learn best.

Another great advantage of this method is that it allows in-class time to be spent on interactive and/or constructive learning activities. These activities should be designed such that they probe for student understanding and common misconceptions, they are used as formative assessments both for instructors and students and they give the students practice at solving whatever types of problems you pose to them.

Checklist #6 – In-Class Activities are Well Designed, Assessed, and Utilized

- In-class activities are clearly defined and explained to the students. This can and often should include open-ended problems, but at least what the students are expected to be doing with their time needs to be clear.
- Students have access to the resources they need to complete the activity. This could be as simple and open-ended as giving them access to the internet and a group with which to work. Sometimes this comes in stages (scaffolding) and includes other students. It's nice to make these situations as close to the "real world" as possible at least by the end of a course, where students are having to ask questions to clarify the problem, thinking about what data they need to gather and gathering it on their own, etc.
- Student groups are made such that each member participates and learns.
- Activities are differentiated so all students attain at least the main learning outcome(s) for the day; top students are also challenged and can advance further.
- The instructor doesn't "take away" the learning opportunity by telling too much!
- Both the students and the instructor learn from the activity how well the students are doing toward meeting the course learning outcomes and have opportunities to adjust and enhance later learning based on the results.
- Assessment results are used to make adjustments in course delivery.

Example: In Heat Transfer last year, we noted that students could calculate a convective heat transfer coefficient on both the homework and quiz immediately following a chapter about that particular type of flow. However, on the final exam students did not do so well at identifying which type of flow they needed to consider and therefore which correlations to use to calculate the heat transfer coefficient. We therefore restructured the content delivery to group common concepts rather than how the book grouped the material, which was by flow type. Similar concepts arise in internal flow, external flow, and natural convection – geometry effects need to be taken into account, flow needs to be characterized, and then the relevant equations need to be chosen and applied. See Figure 1 for an example in-class activity designed to address this issue.

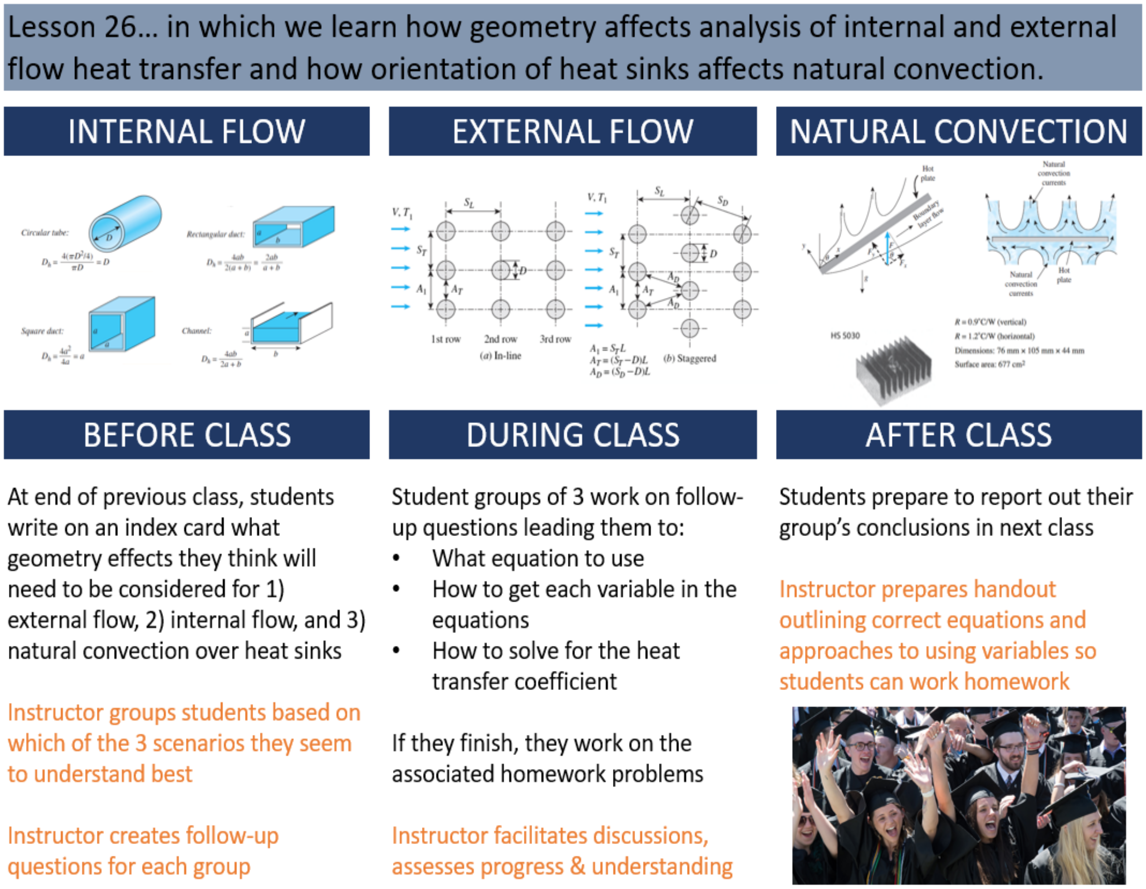

Figure 1 – Example in-class activity plan illustrating who does what when and how.

In this particular activity students are grouped based on what they know, so the groups are more homogeneous than heterogeneous. This works well for this exercise because groups will be able to advance more toward identifying the key parameters and then finding the right equations when working with other students who also understand that same geometry fairly well. Because in this activity we are asking the students to explore the material on their own and for the first time, homogeneous grouping will likely lead to more success than heterogeneous grouping. In some cases though, such as when students have different background information and those with less understanding can learn from those who understand better, heterogeneous grouping can be more beneficial. The follow-up questions for each group in the example given in Figure 1 are designed to get them to figure out the flow regime (laminar vs. turbulent), to search for the relevant fluid properties, and to put it all together to solve for the heat transfer coefficient. In the next class period student groups will report out on what they figured out (with instructor input so the rest of the class doesn't get misinformation) so in the end all of the class will get a complete picture of how to analyze all three scenarios having done an in depth analysis of one of them.

The results of the first implementation of this activity and this new way of grouping the material in Heat Transfer will be available by the time of the conference and will be included in the presentation.

Catch Phrase #4 – "Students (or anyone, for that matter) won't care how much you know until they know how much you care" (J.C. Maxwell)

In my personal opinion, the number one thing any instructor can do to promote student learning is to genuinely care about and believe in their students. It is amazing what students can do when they know that you really care about them. I will close with a few approaches I've taken to assuring my students know that I truly care about them and their success.

1) Learn their names. This is nothing new – many if not most faculty do this and it is a proven method for lowering the activation energy to getting students engaged. I just want to point out to new faculty though that this can be done even if you have 200+ students. I haven't done it with more than 260 in a single semester, but I have done so with that many and will keep trying until I reach a number at which I can't do it anymore (I hope that never happens). Take pictures with their names on day 1 and study them until you know them all by week 2. It's worth it.

2) Life lessons. Each Friday I start class with a life lesson. These life lessons range from financial advice (buy a house rather than renting if you can, sometimes get your paycheck in cash so you can see what money is really worth, realize it's ok and expected that you negotiate for your starting salary, graduate students often get PAID to go to graduate school for a Ph.D. at least in engineering, once you start making a lot of money that doesn't mean you have to adjust your lifestyle – if you can stay used to an inexpensive lifestyle and invest that is better!, etc.) to relationship advice (be a good listener and communicator, call your parents, thank and support the people in service industries every chance you get, think about and work for your partner's happiness as well as your own, realize you almost never know someone else's who background story so always give people the benefit of the doubt and be understanding, etc.) to practical advice (carry jumper cables and know how to change a tire, know at least one person's phone number by heart, etc.) to whatever mistakes I've made recently that I have learned from. They really like hearing about mistakes we make. Tell them in positive ways, emphasizing lessons learned. My students love these and demand a life lesson if I forget. After 3 semesters with the same students I'm starting to have to get creative!

3) Sixth office hour. This is new, but I just decided to start hosting a "sixth office hours" once each week during which time students cannot ask me anything about class but they can *teach me* anything they want (within reason). This shows them I realize I also have a lot to learn, that everyone can learn something from everyone else, and that I care about what they know and are interested in. So far I have learned a little about how perovskites can be used for solar energy conversion, how to write in Mandarin, how to swing dance, and about sodium adsorption ratio and produced water from a drilling operation and how that affects plant life! Today I will learn how to do multiplication (I'm assuming of large numbers) quickly in my head…

Acknowledgements

I have learned many of the truths, ideas, etc. presented in this paper through a combination of my own experiences teaching and learning but also through workshops, courses, discussions, etc. and of course through reading pedagogical literature. I wish to acknowledge in particular Melissa Krebs, Barbara Bath, Ron Miller, John Falconer, Sam Spiegel, Matt Liberatore, Dendy Sloan, Chuck Vestal, and Bob Baldwin, to name just a few of those who have been significantly

influential in helping me gain what understanding I have of how people can effectively learn and teach. The Trefny Innovative Instruction Center's Engineering Learning Intensive (previously known as the Summer Intensive Course Revision Course) at the Colorado School of Mines [12] both introduced me to some new ideas and reinforced and formalized some I had had and experimented with on my own before. Lines have blurred for me between my own ideas and those that have come from readings, discussions, etc. but I certainly learned a ton at that course so credit goes to the course for anything in this paper that has not otherwise been referenced.

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