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# Team Teaching of Thermodynamics: Rapid Instructional Development in Young Academics

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## Introduction

A large undergraduate teaching service course is often viewed as a teaching ghetto, where young academics learn how to teach by doing without any substantial guidance or mentoring. New faculty are often assigned to such courses during the first term of appointment and are expected to perform in the classroom without having formal teaching training or education. These new faculty are immediately confronted with the many content based aspects of university education, including lecture preparation, development of assignments, and writing of examinations. However, the successful educator must devote a similar effort to developing effective and efficient teaching practices based on student learning styles, learning objectives, and cognitive levels appropriate to the level of the course. The time needed to recognize and address diverse student learning styles, be an effective communicator, develop classroom enthusiasm through active learning and effective interaction, and to be flexible in student learning outcomes is often lost to the more urgent need to develop the course content. Consequently, student evaluations of the new instructor's effectiveness and overall course performance are often less than anticipated, and the initial enthusiasm and energy for undergraduate teaching are lost.

In most instances, this is not the result of a lack of effort by the young academic, but rather the constraints of other professional expectations. The time demands placed on these young faculty typically exceed the number of hours in a day and they quickly search for areas to recoup time. With the expectation to "publish or perish" many reduce the effort placed on course development in order to develop their research programs. While many successful educators advocate spending no more than 2 hours preparing for each new lecture, inexperience with preparing a comprehensive lecture coupled with re-learning much of the material frequently means that new instructors exceed this recommended time allotment. The time required outside of the classroom to address student questions for a large service course further reduces the time

young academics can devote to teaching development. As a result, most new educators focus on meeting the minimum technical aspects of a course without sufficient opportunity to focus on student learning and outcomes. Teaching a large service course often magnifies this deficiency and can lead to a negative perception of service courses throughout the faculty and undergraduate students. Consequently, many young academics assume a negative view of undergraduate teaching because of the missed opportunity to develop effective teaching practices.

There are several cornerstones required to build a solid foundation for effective undergraduate teaching. The first is to free up time for young instructors to focus on teaching and student learning, rather than on reinventing content delivery. The second is to direct their attention to the foundations of teaching: effective use of class time, awareness of student learning styles, and alignment of course objectives between lectures, assignments, and examinations. Developing these attributes early in the career of a young academic will provide the basis for future positive classroom and teaching experiences.

**Instructional Development Through Team Teaching**

In the Department of Chemical and Materials Engineering at the University of Alberta, we have made large service courses a vehicle for the development of teaching and classroom skills in new academics. One of the particular successes of this strategy is a multi-section course in thermodynamics (ChE 243) offered to over 700 engineering undergraduates every year. This course is very highly structured, has clearly established objectives, a well-defined pace of lectures, and common assignments, midterms and exams. With at least two parallel sections every term, this format provides an invaluable opportunity to allow young academics the time to focus on student learning and teaching skill development. New instructors are paired with experienced instructors and a team of teaching assistants. The well-defined structure of the course eliminates many of the difficulties and pit falls often encountered on a first trip into the classroom. This course structure has allowed young faculty the opportunity to focus on the development of their teaching and classroom skills by allowing the experienced instructors to define the organization and pace of the course. Consequently, new chemical engineering faculty members at the University of Alberta have the unique opportunity to develop their lectures to accommodate many different learning styles and cognitive levels in order to ensure that all students have the opportunity to master the subject material.

The structure of the course is such that the technical aspects, including the preparation of assignments and exams, are the responsibility of the experienced educator in consultation with the young academic. This not only teaches the new academic effective methods for the preparation of course materials, but it also provides additional time to concentrate on developing teaching skills. Prior to the start of the academic term, the course instructors meet to discuss expectations and responsibilities. By this time, the academic mentor finalizes the course schedule and outline, and the course format and content are discussed with the new academic. The new academic's responsibilities are clearly conveyed, and primarily include developing effective and efficient means to disseminate the course material. Following this initial

discussion, the new academic is given the opportunity to choose the course section that best fits their schedule. This initial discussion reinforces the perceived abilities of the new academic and naturally instills a great deal of enthusiasm for undergraduate teaching. Throughout the term, the mentor prepares two-thirds of the weekly course assignments and actively shares their lecture notes and teaching practices with the new academic. Coupled with weekly meetings with the teaching assistants to discuss homework, the mentor also meets regularly with the new academic to discuss potential areas where students may have difficulty with a specific topic. This affords the new academic the opportunity to adjust their teaching styles and pace to address these topics, thereby averting potential classroom pitfalls.

The midterm and final examinations are prepared as a cooperative effort between the course instructors enlisting the strengths of each academic. Due to the structured content of the course, the examinations follow the same format every term. For the midterm examination, two problems are prepared (i.e. closed system, open system) and the final examination has four problems (i.e. closed system, open system, cycle, departure functions) encompassing the entire course. For the midterm examination, one of the problems is authored by the new academic, while the mentor prepares the other. The new academic has the opportunity to author the problem that suits their technical strengths, and is responsible for grading the problem. The mentor authors the remaining problem, and coordinates the preparation of formulae sheets and the proofing the completed examination for correctness. The final examination follows a similar format, where the exam is expanded to include additional problems again allowing the new academic the opportunity to author the problem of choice. This format allows the new academic to learn the best practices for exam preparation without assuming the full responsibility that comes with sole course instruction. Following the completion of the course, the instructors cooperatively review the term marks and decide on an appropriate grading distribution. This also teaches the new academic the best practices for delineating marks to develop a fair grade distribution based on course performances.

One of the key attributes of this course, and successful implementation to other engineering courses, is the selection of the teaching team and academic mentor. Although the process of team building is not an exact science, recognizing several governing principles can be helpful in assessing a suitable mentor and developing a successful teaching team. First, a majority of the instructors in any given academic term should have previous experience teaching the course and a demonstrated track record of classroom excellence. If the service course includes three separate sections, only one instructor should be new to the course. Second, for those considering adopting this approach for the first time, there needs to be a critical mass of 50% of the instructors who have identified course quality as a priority. One of these instructors should be identified as the course coordinator, and effectively serves as the academic mentor throughout the academic term.

At the University of Alberta, a course coordinator role for a large service course is considered a significant administrative contribution and included in the annual performance report to the Faculty Evaluation Committee. This provides direct incentive for the mentor to ensure teaching and course excellence in every section of the service course. While in principle,

all academics have the ability to provide effective course instruction, not all are ideally suited to be a mentor. In addition to the previously noted attributes, Buckingham and Clifton[1] identify a number of characteristics, which can be used to identify those who will excel in this role. We have found that after identifying an excellent mentor and establishing this culture of mentorship, there is a natural progression through the ranks of the instructional team.

In summary, this format effectively removes many of the responsibilities of course design while supporting the new academic in their (typically) first teaching role. By eliminating the necessity to be consumed with every aspect of course development, the new academic can effectively focus their attention on developing the best teaching practices. This opportunity is further strengthened by the mentorship provided by the senior academic, who has demonstrated teaching effectiveness and excellence. The new academic typically emerges from this first teaching experience with a sense of accomplishment and a renewed interest in undergraduate teaching.

**Instructional Development Through Formal Instruction**

In parallel with the opportunity to team-teach the second year thermodynamics course, our new faculty members are supported through the New Faculty Forums. These forums are a series of weekly lunch hour seminars on a variety of topics of interest to new faculty members. Approximately half of these sessions are devoted to topics related to teaching, and the session which we emphasize in this paper is Learning Styles.

Many academics, especially young academics, tend to teach in the same manner they would like to be taught, not realizing that they typically have a different learning style than the majority of their students. Characteristics of different learning styles are contrasted in Table 1 (modified from Felder, 1993).[2] Comparative data for professors vs. students at the University of Alberta was accumulated over 5 years using the Index of Learning Styles developed by Solomon and Felder (http://www.ncsu.edu/felder-public/ILSpage.html). We encourage the reader to complete this assessment for themselves. Professors in the New Faculty Forums showed a strong preference for visual presentation of information (graphs, figures, maps, diagrams); and for global organization of ideas (extending from the general principle to the specific applications). No strong trends emerge in the other two dimensions: active/reflective learning and sensing/intuitive data awareness. Figure 1 illustrates that our undergraduate students have a consistent preference of learning styles, but it is not well matched to either traditional lecturing without visual aids, or to professors' natural ways of organizing information. Our students have a strong preference for visual presentation of information, and are quite different from their instructors in their preference for sequential presentation of ideas, building up from the specific to the general. This, combined with their preference for active (vs. reflective) and sensing (vs. intuitive) explains the frequent request from our students for more examples. Given this data, instructors are able to see the need to address a variety of learning styles in the classroom.

Many new academics adopt a specific instructional model at the beginning of term, and continue to teach the same way without attention to learning styles and diversity. While the

same teaching style can certainly become monotonous, and actually may dissuade students from learning, the inability to recognize this is a potential pitfall for young academics. Although many of these elements are elementary to experienced faculty, most young academics fail to develop and diversify their teaching styles because they are consumed with the organizational structure (assignments, quizzes, exams, etc) of the course. In fact, upon reflection of personal teaching experiences, most young academics would recognize these attributes are consistent with their best undergraduate classroom experiences. However, when faced with the responsibility of teaching a course, the general approach is to concentrate on the minimum expectations to avoid spending excessive time on teaching responsibilities. This approach undoubtedly results in the young academic focusing on the dissemination of technical material without considerable attention to learning styles and course outcomes. One method to facilitate the development of these attributes in young academics is to provide an academic mentor in the context of a service course who has demonstrated success in the classroom.

These attributes can be learned by the new academic by considering the diversity in undergraduate student learning styles. Indeed, the primary purpose for having new academics complete the learning styles survey is to reinforce the concept that there are many different learning styles, and educators must be able to adapt and accommodate these styles in instructional practices. All students (and academics) learn differently, and therefore, teaching practices should be as diverse as learning styles. The highlighted differences in learning styles (Figure 1) allow the new academic to consider these attributes when developing course content. The ability to realize the diversity in learning, coupled with the opportunity to teach in a well-defined course structure, provide the ideal environment for the new academic to focus on effective teaching styles. As a result, the new academic is provided with the opportunity to change their teaching style to accommodate the learning style of the students. This is not only supported by the structure of the team teaching concept, but the course coordinator provides the necessary mentorship to assist the new academic by offering invaluable suggestions for improvement developed from prior experience. The method in which the new academic varies their teaching style to accommodate classroom diversity depends on several factors. However, when adapting a team teaching concept across the engineering curriculum we are ensuring success by providing an enabling environment.

**Evidence of Success**

The results of this approach in the Department of Chemical Engineering at the University of Alberta have been spectacular. Since 1996, we have hired 25 tenure-track instructors. Of the 7 new instructors who team-taught thermodynamics (ChE 243) as one of their first teaching assignments, 5 have received teaching awards and none have struggled with the teaching component of their work. The four others who have received recognition for their teaching excellence were all introduced to the classroom through team teaching in other courses and have received formal instructional training. A number of these 11 individuals see research as their primary professional interest, but have found that they also enjoy teaching. Of the remaining 14 instructors, 9 have struggled to find their way in the classroom and many reported very negative experiences in their first courses. As a result of the remarkable success of the thermodynamics

model, we have extended team teaching to our design course sequence. We are also incorporating the formal structure and culture of mentoring new instructors in the second major service course in our department.

## Summary

Team teaching in large engineering service courses is an effective and efficient way to promote the rapid instructional development of young academics and experienced academics who are teaching a new course. When structured properly, these courses provide a comprehensive opportunity for young academics to focus on the attributes of an effective engineering educator without being consumed by the content driven aspects (assignments, exams) of course preparation. This allows young academics to learn the best educational practices without experiencing a trial-by-fire, thereby developing a positive attitude towards undergraduate education from the onset.

### References

[1] M. Buckingham and D.O. Clifton, "Now, Discover your Strengths," Free Press (2001).

[2] R.M. Felder, "Reaching the Second Tier: Learning and Teaching Styles in College Science Education," *J. College Science Teaching, 23*(5), 286-290 (1993).

### Biographies

ALAN E. NELSON is an Assistant Professor in the Department of Chemical and Materials Engineering at the University of Alberta. He joined the faculty at the University of Alberta in 2001 after receiving his Ph.D. from Michigan Technological University and Bachelors degree from the University of Minnesota (Duluth). His teaching activities currently include thermodynamics, heat transfer, and reactor design and kinetics.

SUZANNE M. KRESTA is a Professor in the Department of Chemical and Materials Engineering at the University of Alberta. She joined the faculty in 1992, has won several teaching awards, served as Associate Chair (Chemical Engineering) and Associate Chair (Graduate), and developed the New Faculty Forums program. Her teaching interests include fluid mechanics, mixing, process analysis, and design.

**Table 1: Learning Styles**

| Learning Style Pairs | Learning Characteristics | Teaching Response |
|---|---|---|
| **Active** | Process information by immediately engaging in activity through discussion or problem solution. | Incorporate active learning, problem solving labs, weekly assignments. |
| ***Reflective*** | *Read the instructions first. Observe and reflect.* | *Lecture, assign readings.* |
| **Sensing** | Like concrete data, well defined methods, explicit expectations. | Identify key words and classes of problems. Introduce innovation in small steps to build confidence. |
| ***Intuitive*** | *Interested in relationships between ideas, easily bored by repetition, drawn to open ended projects and innovation.* | *Use open ended questions, relate course material to other courses, emphasize ways to check accuracy of results.* |
| **Visual** | Visual information is most easily processed: charts, diagrams, graphs, tables, maps | Use extensive visual aids. Write full sentences out on the board. |
| ***Verbal*** | *Verbal information is preferred: paragraphs, descriptions, lectures* | *Lecture from notes. Write down equations and key words on the board. Explain figures in detail.* |
| **Sequential** | Understanding is achieved in a progression of small incremental steps. | Build up understanding through a series of illustrative examples and applications. |
| ***Global*** | *Understanding is approached globally, through univeral principles. The full picture is needed in order to organize information clearly.* | *Emphasize the general theory. Applications are of secondary interest.* |

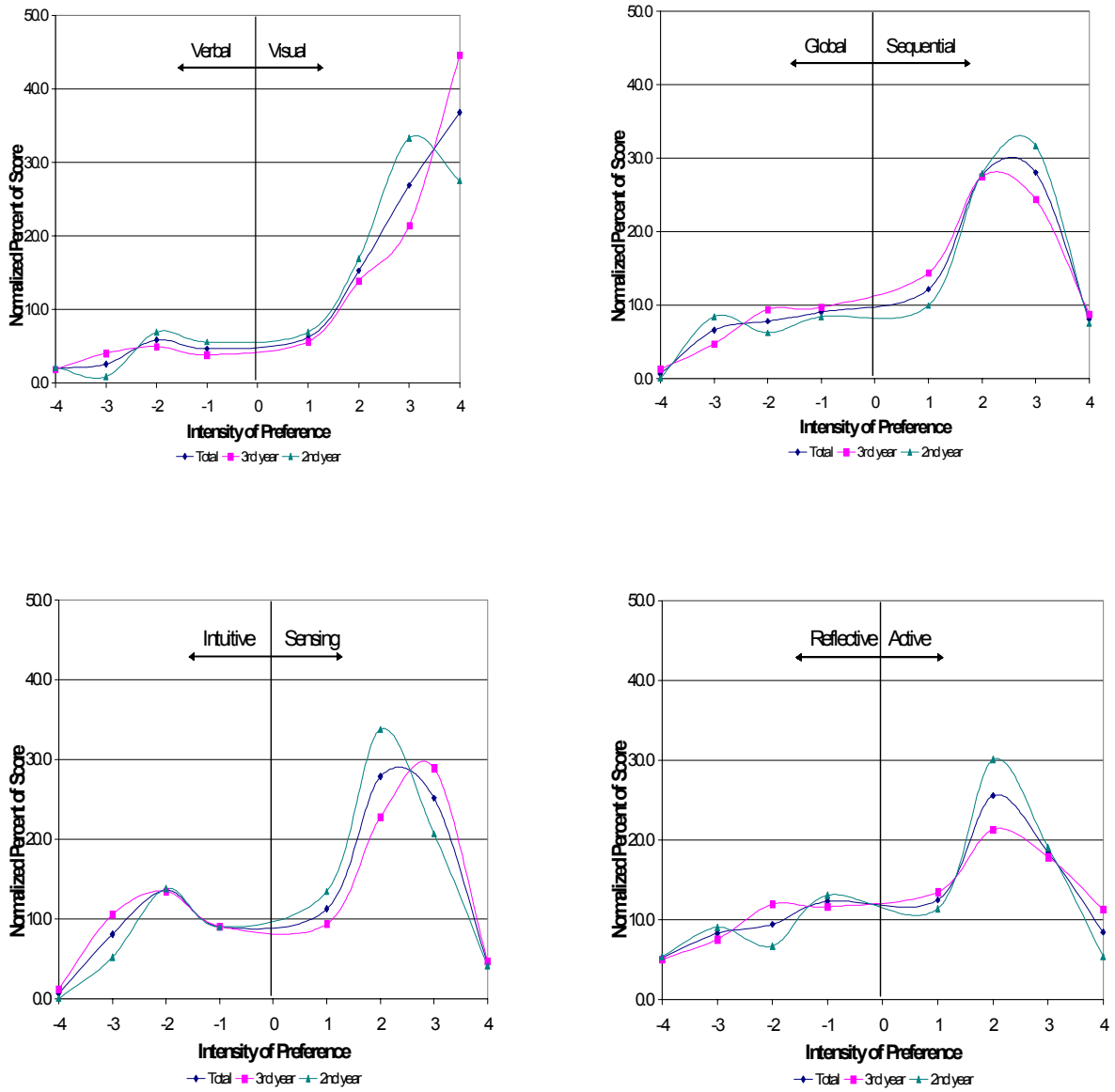


**Figure 1:** Recommended distribution of teaching styles based on learning styles inventory results for second and third year chemical and materials engineering students. There are approximately 150 students in each group and the data was collected over five years. The results are weighted by student number (N) and intensity of preference (I). The product (NI) at each intensity of preference is normalized by the total score (ΣNI). Preferences of ±1 indicate that a student is comfortable with either style. Preferences of ±4 indicate that a student will find it very difficult to learn exclusively using the opposing dimension. While there are clear preferences, it is equally important to note that all dimensions must be addressed in order teach the whole class effectively.