Maximizing team diversity in the Praxis course at the University of Toronto[1, 2]

Professor James ("Jimmy") Rosebrugh sat alone at his desk, concerned about his teaching assignment for next year. He had just been assigned to be the instructor for the Praxis II freshman engineering course at the University of Toronto, which was unlike any course he had taught before due to its large size and structure. Jimmy was concerned because both his colleagues and the upper year students he previously taught told him that forming the right project teams was critical to student success in Praxis II. Thus, one of his main tasks as Praxis II instructor was to ensure that hundreds of freshman students who mostly did not know one another would eventually become high-functioning engineering teams that would be able to solve complex, often unstructured problems.

Jimmy's primary goal was to help train the students to think more creatively during problem solving. In previous years, many teams struggled with interpersonal dynamics issues, which hindered the team's ability to solve the problem at hand. A contributing factor was that team formation was done by the students themselves. After doing some research on team dynamics, Jimmy hypothesized that the creation of more "diverse" teams -- those with students with different and complementary characteristics -- might not only improve their ability to generate creative solutions, but also resolve many of the team dysfunction issues. As a result, he decided to do an experiment this year: he would be in charge of creating teams for one of the sections of the course. Even though it would be more work for him, he believed that he could ultimately improve the quality of the experience for the students. And if the experiment was successful, he would have the evidence to support a broad roll-out the following year. As a bonus, Jimmy would get to put his Operations Research background to good use.

Background

Engineering Science at the University of Toronto
The University of Toronto (U of T) has been consistently ranked as the top engineering school in Canada, and one of the top engineering schools in the world [1, 2]. In the 2013-2014 academic year, the Faculty of Applied Science and Engineering at U of T had 5,489 undergraduate students, 2,194 graduate students and 243 professors [3].

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[1] This case was written by Timothy C. Y. Chan, Derya Demirtaş, Brendan Eagen, Daria Terekhov, solely to provide material for class discussion. The authors do not intend to illustrate either effective or ineffective handling of an educational situation. The authors may have disguised certain names and other identifying information to protect confidentiality.

[2] The authors thank Jason Foster, Sara Scharf and Patricia Sheridan for bringing the described situation to their attention, for helpful discussions, and for allowing the use of material from their study. For detailed information about their work, we refer the readers to their papers [4, 5].

The Faculty of Applied Science and Engineering offers eight direct-entry core engineering programs (chemical, civil, computer, electrical, industrial, materials, mechanical, and mineral), a general-first-year option after which students choose one of the core programs, and the Engineering Science program [6]. While sharing many elements with the core programs, Engineering Science (EngSci) has the highest entrance requirements and is seen as the most challenging and rigorous of the undergraduate engineering programs. The EngSci program consists of two multidisciplinary foundation years and two subsequent years focusing on one of nine majors (aerospace; biomedical systems; electrical and computer; energy systems; mathematics, statistics and finance; physics; infrastructure; nanoengineering; robotics) [7]. Approximately 260 students enter the Engineering Science program every year [8].

Praxis Courses
In addition to fundamental courses spanning the major engineering disciplines, the first-year EngSci curriculum includes two courses focused on engineering design and communication: Praxis I and II. The Praxis courses provide students with an initial experience in engineering design and practice [9]. Praxis I introduces students to design and communication; students work in teams to address multiple design challenges. In Praxis II, teams of students work on a semester-long design project focused on addressing a real issue in the City of Toronto; the students are responsible for all aspects of the project, from identifying and defining the problem, to designing, prototyping and presenting the solutions. Since both Praxis courses are team-based, team composition plays an important role in the success of the projects.

Team Formation Challenges in Praxis II
Teams in Praxis II consist of three or, more commonly, four students. In the past, team formation was done by the students themselves, which resulted in a number of highly dysfunctional teams. The two concrete issues identified by past instructors included [4]

a. [Non-English intra-team communication] When all students on a team shared knowledge of a language other than English, that language tended to be preferred in communication among team members. While this allowed strong within-team communication, it also made external communication, such as class presentations and contact with course instructors, more difficult. Students from such teams later complained about the lack of exposure to English due to peer pressure to speak the other language, and about feeling cut off from the instructor and the rest of the class due to the presence of a dedicated 'translator' on their team.

b. [Language-based exclusion] In teams that consisted of students from various language backgrounds such that at least one person did not speak the shared language of the other team members, language-based exclusion issues ensued. For instance, in groups consisting of three members with a high English proficiency and one member with a low English proficiency, the student with low English proficiency often felt excluded and talked over.

The Praxis II course has been running for more than a decade. Instructors have continuously worked on improving it, including attempts to resolve the team dynamics issues stated above by, for example, formal instruction on teamwork and leadership [10-12].

Diversity in Teams
Diversity in teams has received a substantial amount of attention in the literature. For example, expertise diversity tends to increase performance while age diversity is generally negatively associated with performance evaluated in experimental settings [13-15]. Using a meta-analysis of 108 empirical studies (10,632 teams), Stahl et al. [16] found that cultural diversity, including racio-ethnicity, personality differences, and differences in values and attitudes, is in general positively associated with creativity and satisfaction. In particular, the study revealed that the ability to generate creative solutions, novelty of the ideas, and satisfaction with the team and team performance are higher for more culturally diverse teams. Wolfe et al. [17] and Kayes et al. [18] showed that teams that had members with diverse learning styles performed significantly better at a complex computer business simulation and a critical thinking task as compared to homogenous teams. Most notably, Halstead and Martin [19] found that engineering student teams that were formed to include diverse learning styles functioned better that self-selected teams. Hall [20] also reported difficulty with self-selected teams that tended to group on the basis of friendship, based on a study of final year Bachelor of Arts in Information Studies students at Leeds Metropolitan University.

Diversity in Praxis II
Students in the Praxis II course are relatively uniform in age and, due to the stringent admissions requirements of the EngSci program, are fairly similar in academic aptitude. However, these students are diverse in other ways. A study done in Winter 2014 investigated three dimensions of student diversity in Praxis II: languages spoken, working style and learning style.

Language diversity
Language diversity was evaluated by an online language proficiency survey developed by S. Scharf [4]. Examples of questions asked in the survey can be found in Appendix I. It was determined that students in the Winter 2014 Praxis II class spoke 26 different languages, as shown in Figure 1.
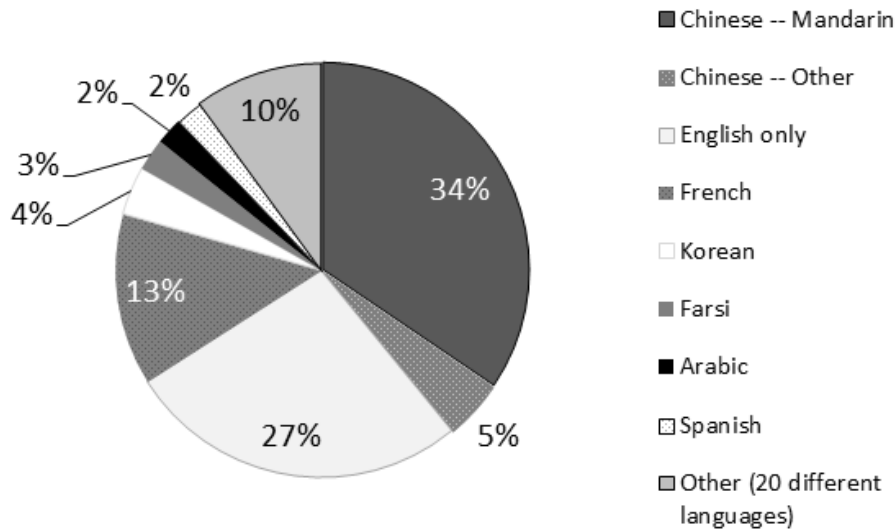
Figure 1. Composition of the Winter 2014 Praxis II course based on language capability. "Other" includes Bangla, Belarusian, Filipino (Tagalog), Finnish, German, Hebrew, Hindi, Japanese, Malay, Polish, Punjabi, Romanian, Russian, Serbo-Croatian, Sinhala, Tamil, Telugu, Tibetan, Turkish, and Urdu. This figure is reproduced from the paper by Scharf et al. [4], with the permission of the author.

Working style diversity

Student working styles were evaluated via the Bolton & Bolton preferred working style questionnaire [21]. The Bolton & Bolton working style inventory (Appendix II) classifies each person into one of the four working styles: analytical, driver, amiable, and expressive. The results of the survey are presented in Figure 2.
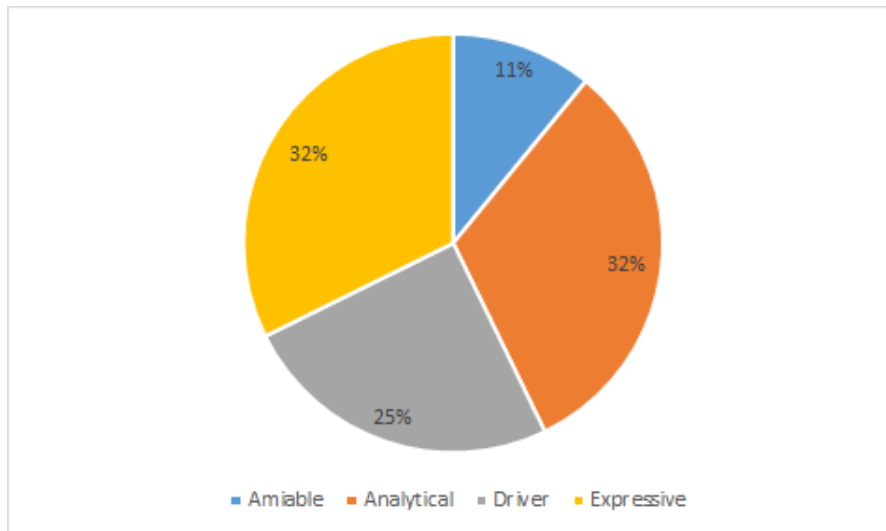

Figure 2. Composition of the Winter 2014 Praxis II class based on the Bolton & Bolton working style survey.

Learning style diversity

Learning styles were categorized using the Felder & Soloman test (Appendix III, see www.engr.ncsu.edu/learningstyles/ilsweb.html for the complete test). The test identifies characteristics along four dimensions (sequential/global, visual/verbal, sensing/intuitive, active/reflective) of a learning style model formulated by Felder and Silverman [22]. While the test positions each student's style along a spectrum within each dimension, the study conducted in Praxis II classified each student into one of $2^4 = 16$ possible combinations (since there are two options in each of the four dimensions). For example, a student could be classified as being Sequential, Verbal, Intuitive and Active. The results of the survey are presented in Figure 3.
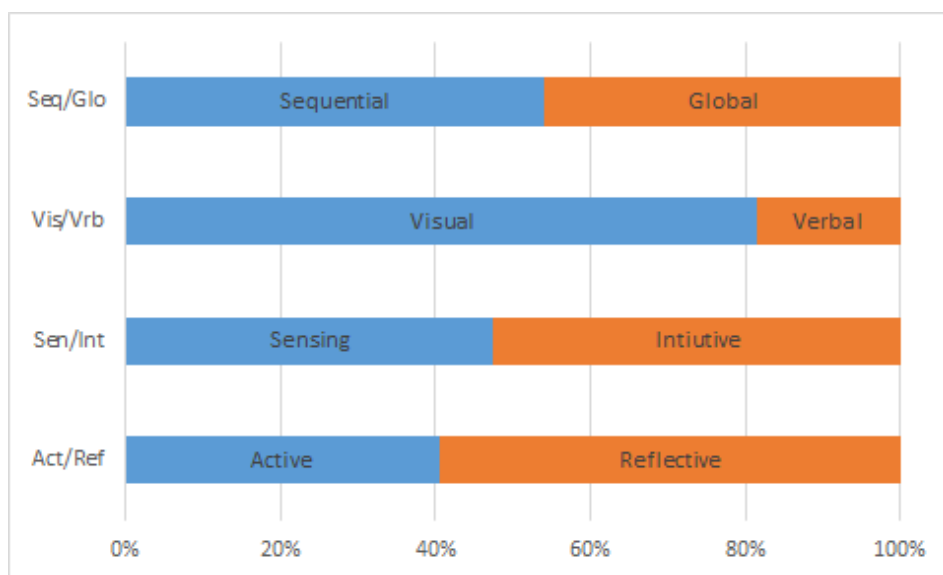

Figure 3. Composition of the Winter 2014 Praxis II class based on the Felder & Soloman index of learning styles.

Problem Description

The coming Praxis II course would be split into several sections and Jimmy chose a section with 96 students for his experiment. He managed to survey that section ahead of time to gather data on languages, learning styles, and working styles. He found that each student spoke at least one of the following 16 languages: English, Arabic, Chinese, Farsi, French, German, Hindi, Japanese, Korean, Malay, Russian, Serbo-Croatian, Spanish, Tamil, Urdu, and Other. He also determined the learning and working style for each student, based on the systems described above. Jimmy felt that teams with maximal diversity along the three dimensions would be best. Diverse teams would have a student representing a mix of languages, learning styles, and working styles. There seemed to be many possible ways to quantify team diversity -- Jimmy would have to justify his choice.

Although Jimmy wanted to have control over the team formation process, he also wished to incorporate the students' preferences for teammates as much as possible, so that students would feel they had some input into the process. Therefore, he also asked the students to list at most five people in the class with whom they would like to work, and at most five people with whom they would *not* like to work. Jimmy aimed to incorporate these preferences as best he could.[3]

Looking at the data, it quickly became obvious that the problem of creating diverse teams was too complex to solve by hand. "This is an opportunity to put my Operations Research knowledge to good use," he thought to himself.

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[3] All data is available as a case supplement. A description of the data format is given in Appendix IV.

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Appendix I: Survey of Languages Spoken (partial survey)

1. Do you speak, read or write any language other than English? [Y/N]

2a. Here are some of the languages most commonly used among engineering design students at the University of Toronto. Please indicate which of the following languages you use. If you use a language not listed here, please select "Other." You will be asked to specify the other language(s) you use in the next question.

Language	
Arabic	☐
Chinese (any dialect)	☐
Farsi	☐
French	☐
German	☐
Hindi	☐
Japanese	☐
Korean	☐
Malay	☐
Russian	☐
Serbo-Croatian	☐
Spanish	☐
Tamil	☐
Urdu	☐
Other	☐

Appendix II: Bolton & Bolton Preferred Working Style Survey

a. *Questionnaire*

Preferred Working Style (Behavioral) Inventory

Be sure to select one statement from each of the pairs. Be sure to put the 'X' in the correct box.

1.			More likely to lean backward when stating opinions
			More likely to be erect or learn forward when stating opinions
2.			Less use of hands when talking
			More use of hands when talking
3.			Demonstrates less energy
			Demonstrates more energy
4.			More controlled body movement
			More flowing body movement
5.			Less forceful gestures
			More forceful gestures
6.			Less facial expressiveness
			More facial expressiveness
7.			Softer-spoken
			Louder voice
8.			Appears more serious
			Appears more fun-loving
9.			More likely to ask questions
			More likely to make statements
10.			Less inflection in voice
			More inflection in voice
11.			Less apt to exert pressure for action
			More apt to exert pressure for action
12			Less apt to show feelings
			More apt to show feelings
13.			More tentative when expressing opinions
			Less tentative when expressing opinions
14.			More task-oriented conversations
			More people-oriented conversations
15.			Slower to resolve problem situations
			Quicker to resolve problem situations
16.			More oriented towards facts and logic
			More oriented toward feelings and opinions
17.			Slower-paced
			Faster-paced
18.			Less likely to use small-talk or tell anecdotes
			More likely to use small-talk and tell anecdotes
__ __ __ __			TOTAL THE NUMBER OF X's DOWN EACH COLUMN
L vs. R	A vs. B		Circle the higher value: Left vs. Right, Above vs. Below

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b. *Description of Working Style Categories*

Preferred Working Style

Analytical	Driver
• Tend to be a perfectionist • Sets high standards and want things done right • Detail is important • Well-organized, 'by the book' • Needs data and information • Not a risk taker • Agonizes over decisions • Work well alone or with a small number of people • Body language: lean back, small gestures, not much eye contact, or facial expression • Quietest of styles: speak less often and think through before speaking • Tend to be indirect when making statement • Tend to speak facts of case not the feelings	• Tend to be results focused • Like fast paced environment • Most practical style: set high realistic goals • Like something to be done, and therefore make quick decisions even if only 55% sure • More likely to change mind over point of view • Excel in time management • Body language: erect, lean in, move fast, small less flowing gestures, serious facial expressions • Forthright in stating opinions and in making requests • May have sincere concern for people, but just don't show it as much
Amiable	**Expressive**
• Tend to be a team player • Likes working in small groups or with another person • Doesn't seek the spotlight, • Tend to encourage others • Listens to what others have to say • Can get sidetracked helping others if others asked • Indecisive at decision-making but good at maintaining work structures • People-oriented: very easy-going and friendly • Doesn't speak a lot, and often slow in forming opinion until late in session • Often withholds judgment or criticisms	• Most flamboyant of styles • Thrive in limelight: like to tell jokes, be centre of attention etc. • Very energetic and always on the go • Like to socialize and work in groups • Dreamers—good vision and imagination • Like to talk in terms of broad generalizations • Often act first and think later • Body language: flowing gestures, lots of facial expression • May talk a lot in discussion • Tend to think out loud • Tell it as it is • People oriented

Appendix III: Felder & Soloman Index of Learning Styles

a. Partial Questionnaire

INDEX OF LEARNING STYLES[*]

DIRECTIONS

Enter your answers to every question on the ILS scoring sheet. Please choose only one answer for each question. If both "a" and "b" seem to apply to you, choose the one that applies more frequently.

1. I understand something better after I
   a) try it out.
   b) think it through.

2. I would rather be considered
   a) realistic.
   b) innovative.

3. When I think about what I did yesterday, I am most likely to get
   a) a picture.
   b) words.

4. I tend to
   a) understand details of a subject but may be fuzzy about its overall structure.
   b) understand the overall structure but may be fuzzy about details.

5. When I am learning something new, it helps me to
   a) talk about it.
   b) think about it.

6. If I were a teacher, I would rather teach a course
   a) that deals with facts and real life situations.
   b) that deals with ideas and theories.

7. I prefer to get new information in
   a) pictures, diagrams, graphs, or maps.
   b) written directions or verbal information.

8. Once I understand
   a) all the parts, I understand the whole thing.
   b) the whole thing, I see how the parts fit.

9. In a study group working on difficult material, I am more likely to
   a) jump in and contribute ideas.
   b) sit back and listen.

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[*] Copyright © 1991, 1994 by North Carolina State University (Authored by Richard M. Felder and Barbara A. Soloman). For information about appropriate and inappropriate uses of the Index of Learning Styles and a study of its reliability and validity, see <*http://www.ncsu.edu/felder-public/ILSpage.html*>.

b. *Description of Learning Styles*

ACTIVE AND REFLECTIVE LEARNERS
- Active learners tend to retain and understand information best by doing something active with it--discussing or applying it or explaining it to others. Reflective learners prefer to think about it quietly first.
- "Let's try it out and see how it works" is an active learner's phrase; "Let's think it through first" is the reflective learner's response.
- Active learners tend to like group work more than reflective learners, who prefer working alone.
- Sitting through lectures without getting to do anything physical but take notes is hard for both learning types, but particularly hard for active learners.

SENSING AND INTUITIVE LEARNERS
- Sensing learners tend to like learning facts, intuitive learners often prefer discovering possibilities and relationships.
- Sensors often like solving problems by well-established methods and dislike complications and surprises; intuitors like innovation and dislike repetition. Sensors are more likely than intuitors to resent being tested on material that has not been explicitly covered in class.
- Sensors tend to be patient with details and good at memorizing facts and doing hands-on (laboratory) work; intuitors may be better at grasping new concepts and are often more comfortable than sensors with abstractions and mathematical formulations.
- Sensors tend to be more practical and careful than intuitors; intuitors tend to work faster and to be more innovative than sensors.
- Sensors don't like courses that have no apparent connection to the real world; intuitors don't like "plug-and-chug" courses that involve a lot of memorization and routine calculations.

VISUAL AND VERBAL LEARNERS
- Visual learners remember best what they see--pictures, diagrams, flow charts, time lines, films, and demonstrations. Verbal learners get more out of words--written and spoken explanations. Everyone learns more when information is presented both visually and verbally.

SEQUENTIAL AND GLOBAL LEARNERS
- Sequential learners tend to gain understanding in linear steps, with each step following logically from the previous one. Global learners tend to learn in large jumps, absorbing material almost randomly without seeing connections, and then suddenly "getting it."
- Sequential learners tend to follow logical stepwise paths in finding solutions; global learners may be able to solve complex problems quickly or put things together in novel

ways once they have grasped the big picture, but they may have difficulty explaining how they did it.

Appendix IV: Description of Excel Spreadsheet

Jimmy gathered the results of the surveys from the current class in an Excel spreadsheet with the following format. For learning style, working style, and language, a "1" shows that the student has the corresponding attribute or speaks the corresponding language, and a "0" shows otherwise. The "likes" sheet lists all student pairs in which the student in the first column would like to work with the student in the second column. Lastly, the "dislikes" sheet contains a binary matrix in which a "1" in row i, column j indicates that the student in row i does not want to work with the corresponding student in column j.