International Journal of Engineering Education Vol. 28, No. 1, pp. 183–191, 2012
Printed in Great Britain
0949-149X/91 $3.00+0.00

Identifying Language as a Learning Barrier in Engineering*

CHIRAG VARIAWA and SUSAN MCCAHAN
Faculty of Applied Science and Engineering, University of Toronto, 5 King's College Road, Toronto, ON. M5S 3G8 Canada.
E-mail: mccahan@mie.utoronto.ca

The language used in engineering course materials may be a barrier to accurate assessment because students perceive the meanings of words differently. Universal Design in Education (UDE) has emerged as a strategy for making course material more accessible, but remains largely untested in this area. This study investigates whether students can accurately self-assess their understanding of vocabulary, i.e. if this is a 'visible' or 'invisible' deficit from the student's point of view, using a limited sample of ten words found in engineering exams. This is a preliminary investigation toward testing the efficacy of a UDE-based mitigation strategy, and it finds that students often inaccurately self-assess their understanding of language used in engineering examinations.

Keywords: language; accessibility; learner-centered

1. Introduction

Often when we think of accessibility issues in higher education what comes to mind are physical barriers to the access to facilities for students or staff. However, increasingly we are aware of, and are trying to address, more subtle obstacles that may create unnecessary challenges that impact student success. These include creating appropriate support systems for students with learning disabilities, and other 'invisible' disabilities. More recently, we have begun to recognize barriers that become perceptible as the student population diversifies. As engineers, we are ideally situated to address this as a design problem because we recognize that designing for a broader set of users has the potential to improve the design of a system for everyone.

The principles of universal design were first articulated in the 1960s and 1970s by Ron Mace and others in the field of architecture [1, 2]. Fundamentally, the goal of universal design in architecture is to design a building or space that is intentionally accessible to the broadest possible range of people. Conceptually this means taking accessibility into account from the beginning of the design process rather than as an afterthought. The accessible design movement played a role in the development of legislation [3, 4]. As a result, many of our university and college environments are now more physically accessible.

In the last two decades the principles of universal design have found their way into a number of other fields, notably engineering. The principles of universal design in engineering have given rise to the development of accessible transit systems, accessible information technology systems, and ergonomically designed household products. The use of universal design in information technology is now pervasive: televisions come with built-in closed captioning systems; text messaging is a standard feature on cell phones; screen magnifiers and readers are readily available; and ATM machines have Braille lettering on the buttons. Universal design features are now built into many systems, allowing the user to create a customized environment that fits their needs (e.g. Web 2.0). Design engineers have moved from a mentality of human-centered design to interaction design and, most recently, to experience design. In doing so, the concept of creating a system that is barrier-free and intuitive for a diverse set of users has become a central theme in the engineering design process.

Universal design has now begun to permeate education, first at the K-12 level and more recently at the postsecondary education level [5]. If we look at a course, a curriculum, or an institution as a designed system, then the principles of universal design should help guide us toward a more accessible learning environment design for a more diverse user group. There have been a number of authors who have re-interpreted the principles of universal design to make them applicable to educational systems [5–7]. The universal design framework applies the principle of 'learner-centered' not just to an individual class, but to the design of the whole learning environment at every level. McGuire, Scott, and Shaw suggest that universal design in education (UDE) is a 'paradigm shift' that promotes uniformity of academic goals and standards by designing accessibility into a course, curriculum, and institution, rather than making exceptions for individual students who do not fit our preconceived idea of what is 'typical' [6]. They point out that individualized accommodation will still be necessary for some students. However, pervasive use of exceptions may undermine the integrity of a course,

* Accepted 23 November 2011.

whereas designing accessibility into a course opens up learning opportunities for a broad range of students. However, they have also noted that UDE remains a largely untested strategy that requires further testing and validation. Pliner and Johnson discuss UDE in relation to social justice and transforming social relationships, which can be negatively affected by invisible barriers to inclusivity [7]. Their work suggests that implementing UDE pedagogy creates a more 'inclusive' environment that can decrease the barriers to learning that all individuals may have to some extent (i.e. the so-called 'curb cut' effect).

A recent review of the literature shows that there is serious concern about barriers to success for students, in both engineering and other fields, and a wide variety of approaches has been employed to try to mitigate barriers for at-risk students [8]. UDE offers one possible approach and a framework for interpreting the impact of mitigation tactics. It will serve as a useful context for considering the results of this study. However, we should also bear in mind that UDE is not the only possible approach and other ways of thinking about these issues should be utilized.

2. Purpose

A look at today's educational institutions shows a dramatic increase in the cultural diversity of the student population, and institutions have not fully evolved to account for this diversity. One example is the use of colloquial language or culturally specific references on assignments and other learning materials. The student's inability to understand a question on an assignment, for example, can create a misalignment between the results of the assessment and the learning objectives of the course. Basically, it compromises the validity of the assessment because it may test colloquial vocabulary to some extent rather than just the engineering concepts. While virtually all assessment instruments have this issue, in engineering it can be a particular problem because it is pedagogically preferable to situate problems in an authentic context and use terminology that is authentic to practice in the profession. This inaccessibility can cause a bias in the assessment, favoring those individuals who have a particular background.

In engineering assessments, students may find questions difficult to answer if they are not familiar with the non-course-related terminology used. In the case of an assignment, the student can get help understanding the question. However, in a closely-supervised exam situation, which is often time-limited, it is usually not possible to get assistance. In our experience, words such as 'blob' or 'kettle' are not specific to the engineering course material being taught, yet they present a problem for some students when they appear on tests. Students knowing the meaning of the word will have less difficulty in understanding the question, and ought to be able to answer it correctly, as intended. Students not having any exposure to the word beforehand, but having sound knowledge of the course material and the English language otherwise, will not be able to understand exactly what is being asked. This concern is balanced by a need to ensure that students graduate with a vocabulary that allows them to operate effectively in the profession. A broad vocabulary is a professional asset. So, ideally, we would want students to acquire a robust vocabulary but this is generally not specified in our learning objectives, and not explicitly taught or assessed.

This vocabulary problem perennially arose in our large first-year design course. Although we tried to write tests using clear, non-culturally specific language we continued to experience problems. We did not want to 'dumb-down' the language because we felt that it is important to use accurate and authentic terminology. Therefore, we took steps to mitigate the problem using the principles of UDE. We now develop a word list, which is posted prior to each test in this course. This word list contains all of the infrequently used words (i.e. we leave out words such as 'and', 'the', 'are', etc.) that appear in that particular test. We put some extra words on the list that do not appear in the test but which are words that we think are useful for an engineer to know. The word list is in alphabetical order, so the questions on the exam are not apparent from the list. The intent is to give the students an opportunity to gauge their own level of understanding of the test vocabulary beforehand and, if required, to consult information sources to correct any gaps ahead of time. This strategy allows us to contextualize questions and use accurate, authentic engineering terminology. However, this practical and simple approach to dealing with the problem is predicated on several key assumptions, only a subset of which is investigated by the study. Some of the broader assumptions include:

1. That the use of common, but infrequently used, words and terms may compromise the validity of the assessment for some students. We are relatively certain that this is true, based on experience, but research data on the frequency and degree of the problem is not available. In addition, there is currently no existing data about language in engineering examinations.
2. That, given a list of words, students can correctly assess their level of understanding of these words. To make good use of the word

list this must be true, but we have no research that supports this assumption. This study attempts to generate some data to test this assumption.

3. That students can independently learn the meaning of the words and phrases on this word list effectively. Again, to make good use of the word list, this must be true, but we have no research that supports this assumption.

This study begins to address the second assumption. The primary objective of the broader study is to analyze how well students can self-assess their understanding of problematic words that could appear in engineering assignments or tests, i.e. to identify whether or not infrequently used words are an invisible or visible barrier for students. This is the beginning of a long-term study to describe the accessibility issues that arise from language in engineering learning materials, and develop tools for addressing this issue (if we find it exists). The specific element of this larger study that we are examining here is whether students can correctly assess their understanding of non-course-related words used in engineering examinations. While it is relatively easy to measure how the addition of a ramp in place of stairs makes a building more accessible for many types of users, it is more challenging to test how a change aimed at reducing language barriers in an engineering course could result in improved learning for a variety of people. However, applying the principles of UDE has the potential not only to result in improvements for people who would otherwise be 'at-risk' but also improve the quality of the learning environment for a broad range of students (i.e. the so-called 'curb cut effect'). Other concurrent concerns are maintaining the integrity of the learning objectives and the economic feasibility of changes to the system.

Within this type of potential barrier the authors chose to focus their attention on three categories of colloquial language prevalent in engineering examinations, namely:

1. non-course-specific technical terminology,
2. culturally-based words, and
3. linguistically-difficult terminology.

These categories are very rough, and there is overlap between them, but we developed these approximate groupings based on examination of the word lists we had prepared for our first-year design course exams over a number of years. It is worth noting that while the authors did not find any pertinent literature suggesting such groupings, literature in areas such as composition studies and linguistics may inform the development of such rough categorization by viewing them from unique perspectives that take into account language development.

The first category contains words commonly used in North American society that have reference to technology. Examples of such words or short-phrases include: mouse pad, power bar, remote control, and ear buds. The second category, culturally-based words, includes words that are used only regionally or within a specific culture. For example, a 'typical' North American would be familiar with the 'hood' of an automobile, whereas a 'typical' Western European would refer to it as the 'bonnet'. Further examples of such words and phrases include: loonie, Jell-O®, an efficiency apartment, and flapjack. There are, of course, words that fall into both the technical terminology and culturally-based word categories. An example is 'coordinates' (i.e. email address), which is used in some regions of the world but is not common in the U.S. This is both cultural and technical. However, for this preliminary study we assigned words to only one of the three categories for simplicity.

The third category that we have used for the classification is 'linguistically-difficult' terminology. Essentially, words in this category fall into neither the first nor the second classification, are not course-specific, yet may cause difficulty for students in understanding the elements of an engineering assessment because they are outside the everyday vocabulary of students. Examples of such words include: propagate, succinct, and happenstance.

3. Design/method

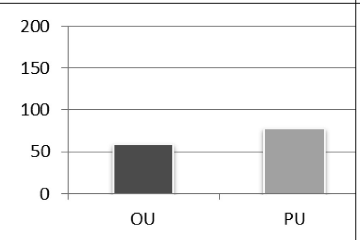
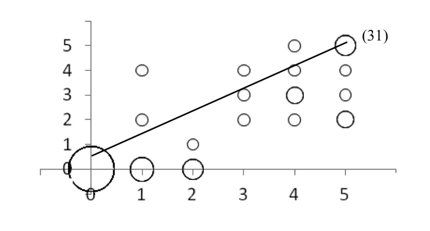
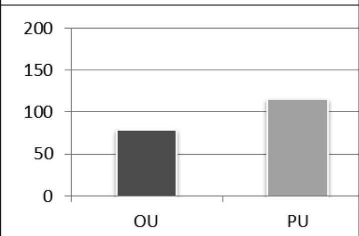
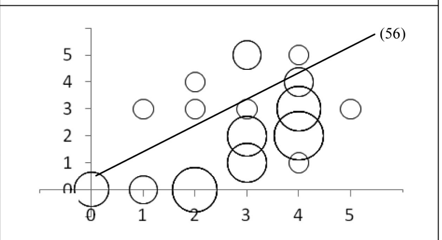
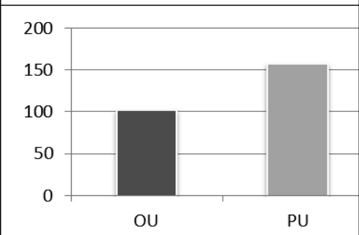
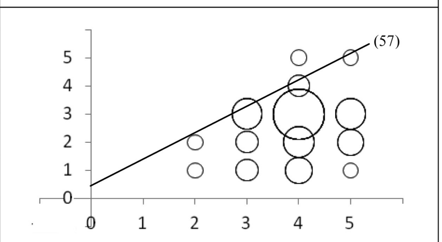
Our study analyzed the responses of forty very diverse undergraduate engineering students who each completed a questionnaire containing ten words that might be found on an assignment or test. The participants for this study represented a mix of very diverse ethnic and cultural backgrounds; a variety of native and non-native speakers of English; representation of different genders; and were all aged 18–22 (typical undergraduate student age). These words were chosen by the authors because they fit fairly well into one of the three categories that we are interested in exploring. In this preliminary study no attempt was made to choose the words using a more systematic method. After fulfilling the ethics process at our institution, the study began by training the participants: they learned about the task they were being asked to perform; the scale they would be using; and the motivation for the study. This was meant to establish a clear purpose to this study and motivate the participants to provide genuine answers. Then, the participants individually numerically assessed their understanding of each of ten words on a questionnaire on an equal interval scale from '0' to '5'; with '0' representing no knowledge of the word, and '5' representing superior understanding. This is the 'perceived-understanding' (PU) score. These words represented the three categories mentioned, and a detailed explanation of the rating scale was provided on the question sheet to minimize ambiguity. Finally, each participant was asked to write a maximum of five synonyms and/or a brief definition of each word within a textbox to provide evidence of their level of understanding. To reduce ambiguity, the most recent *Oxford English Dictionary*'s (*O.E.D.*) definition of 'synonym' was written as a footnote on the question sheet, and participants were free to ask questions at any time. The researchers then consulted the *O.E.D.* for the correct definitions and synonyms for each of the ten words used in the study. The responses from each participant were compared against these dictionary definitions by the researchers and given a score. We counted the definition as fully correct if it matched in meaning to at least one of the definitions of the word. The closeness of correlation between the dictionary definition and the student's definition was assigned an integer value from 0 to 5; this is the 'observed-understanding' (OU) score. Finally, the participant's PU score was compared with the OU score.

4. Results

Table 1 shows the words used in the study. Below each word, in parentheses, is the category that best describes the word. To the right of the word is a histogram comparing the sum of the OU and PU scores. The graph in the right-hand box of each row shows the relationship between these scores, based on occurrence. The larger-diameter circles indicate a larger proportion of participants having that specific outcome. Although only ten words were used in this investigation, the number of participants resulted in a substantial data set requiring further methods of analysis. Table 2 shows a summarized ANOVA for the statistical significance of the findings, in addition to Figs 1 and 2 that examine the aggregate data of all words combined.

Figure 1 shows the frequency of the difference between OU and PU for all of the words together. Ideally, an accurate self-assessment would mean

Table 1. Individual analysis of each word. The sum of scores graphs show overall confidence and relative difference in OU and PU scores. The scatter-plots show interaction effects

Word	**Histogram: Sum of score** The left bar represents the sum of perceived-understanding (PU) scores. The right bar represents the sum of observed-understanding (OU) scores.	**Scatter-plot data** x-axis: perceived-understanding scores (PU). (student's self-assessed understanding). y-axis: observed-understanding scores (OU). (understanding assessed based on written definition). The number in parenthesis is the sum of absolute differences from each data point to the line PU = OU ($y = x$).
Succinct (Linguistic) OU/PU = 0.76		
Propagate (Linguistic) OU/PU = 0.69		
Feasible (Linguistic) OU/PU = 0.65		

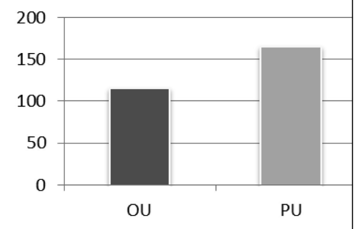
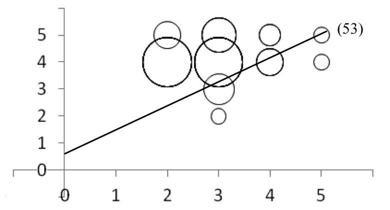
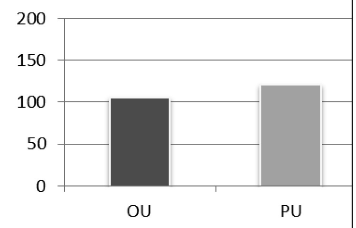
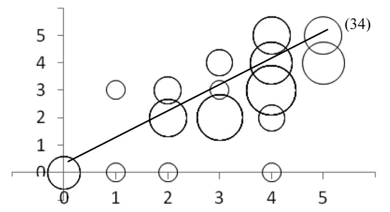
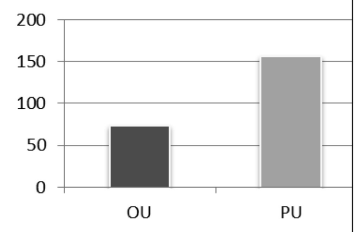
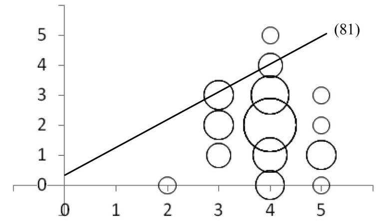
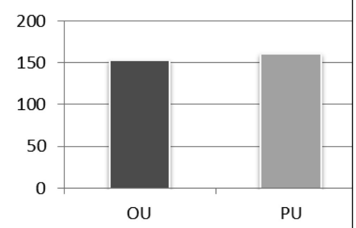
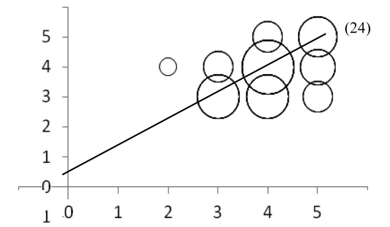
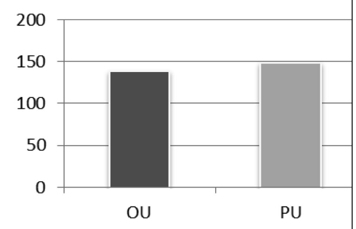
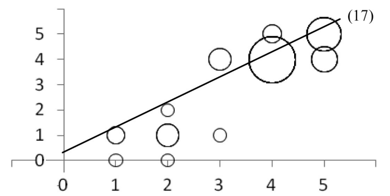
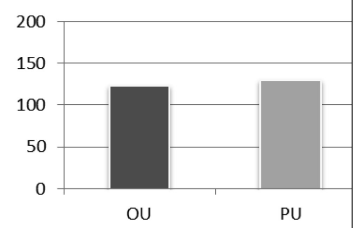
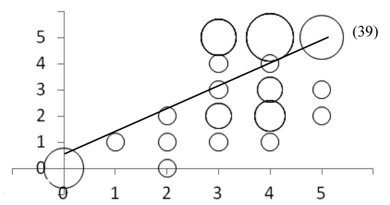
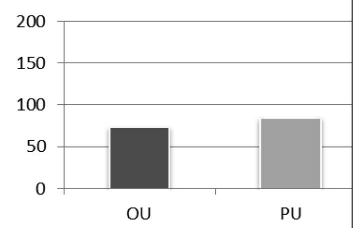
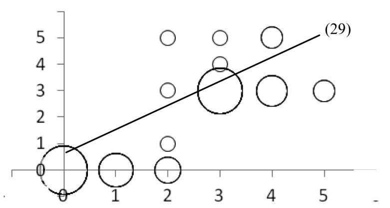
Field (Linguistic) OU/PU = 0.70		
Mold (Technical) OU/PU = 0.87		
Tolerance (Technical) OU/PU = 0.47		
Fax (Technical) OU/PU = 0.95		
Jell-O® (Cultural) OU/PU = 0.93		
Bungalow (Cultural) OU/PU = 0.95		
Bonnet (Cultural) OU/PU = 0.87		

Table 2. Statistical significance of accurate self-assessment.

Word		Means	St. dev.	PU-OU means	PU-OU St. dev.	t-test
Bonnet	PU	2.1	1.582	0.275	1.062	t(39) = 1.64, p = 0.109
	OU	1.83	1.81			
Bungalow	PU	3.25	1.565	0.175	1.338	t(39) = 0.83, p = 0.413
	OU	3.08	1.94			
Fax	PU	4.03	0.800	0.200	0.883	t(39) = 1.43, p = 0.160
	OU	3.83	0.747			
Feasible	PU	3.93	0.797	1.375	1.125	t(39) = 7.73, p = 0.000
	OU	2.55	1.011			
Field	PU	4.13	0.686	1.250	1.056	t(39) = 7.49, p = 0.000
	OU	2.88	0.822			
Jell-O	PU	3.73	1.219	0.250	0.742	t(39) = 2.13, p = 0.040
	OU	3.48	1.585			
Mold	PU	3.03	1.310	0.400	1.105	t(39) = 2.29, p = 0.028
	OU	2.63	1.462			
Propagate	PU	2.88	1.285	0.900	1.336	t(39) = 4.26, p = 0.000
	OU	1.98	1.544			
Succinct	PU	1.95	1.974	0.475	1.132	t(39) = 2.65, p = 0.011
	OU	1.48	1.853			
Tolerance	PU	3.90	0.672	2.075	1.385	t(39) = 9.48, p = 0.000
	OU	1.83	1.174			

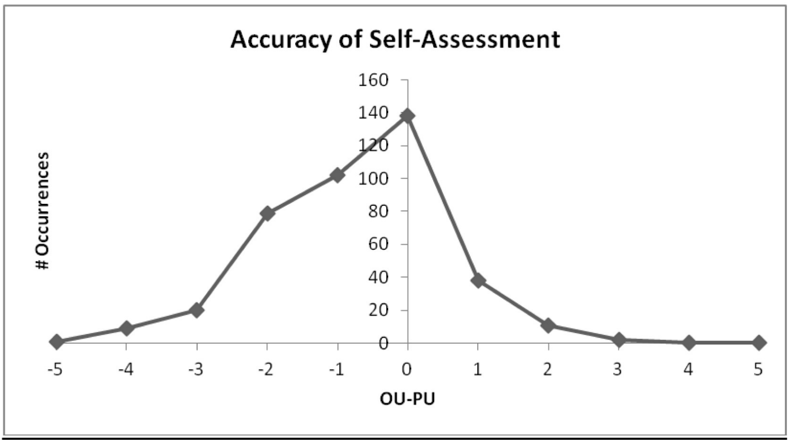


Fig. 1. Number of times the self-assessment is ideal (OU-PU = 0) and the general tendency towards over-assessment (OU-PU < 0). This is an aggregate of all words used in this study.

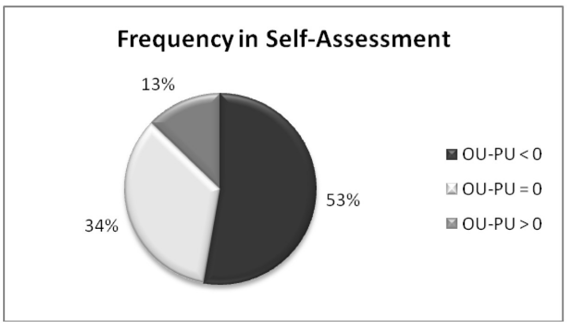


Fig. 2. Pie chart showing that the relative frequency of over-rating understanding is greater than accurate and under-rating understanding combined. This is an aggregate of all words used in this study.

that the OU and PU scores would be identical (OU-PU = 0). The data, however, shows that OU and PU scores were quite often different. The skew in Fig. 1 demonstrates visually that participants were more often over-rating their understanding of the words, and the bar charts in Table 1 and the pie chart in Fig. 2 reiterate this point. We found that students correctly self-assessed their understanding 34.5% of the time and overrated their understanding 52.8% of the time; they only under-rated their own understanding 12.8% of the time as summarized in Fig. 2.

When we examined the OU/PU ratio for each word (Table 1, left column), we see that there are noticeable differences between words. Words such as 'bungalow', 'fax', 'Jell-O', 'bonnet' and 'mold' have an OU/PU ratio relatively close to 1, suggesting that students are more likely to correctly self-assess their understanding of these words. Conversely, the OU/PU ratio tells us that students are less likely to correctly self-assess their understanding of words such as 'tolerance', 'feasible', 'propagate' and 'field'. This is important because, although words like 'bonnet' have a low overall PU and OU, students are apparently aware of their lack of understanding, which makes this type of word a visible learning barrier for them.

The data also show that students believe they understand some of these words well; these words have higher PU scores relative to the other words. For example, the students think they know the word 'tolerance' better than the word 'bonnet', however the observed-understanding scores of these two words are quite similar. Table 1 shows that the words 'field', 'fax', and 'feasible' are known to many of the participants; however, the students substantially overrated their understanding in several of these cases.

To better understand the accuracy of self-assessment, we calculated the residual of each data point to the line PU = OU for each word (shown in parenthesis in the scatter-plots in Table 1). This number is calculated by taking the sum of the absolute differences for each data point to the line PU = OU. The results show that a word like 'tolerance' is consistently misjudged, since it has a high residual relative to the other words. In this study, smaller residuals suggest a more accurate self-assessment. For example, the scatter-plot for 'fax' is skewed and clustered to the upper-right (Table 1), so it is difficult to interpret the data from the scatter-plot alone. However, it has a relatively small residual relative to other words, which demonstrates that students are typically correctly self-assessing their understanding of this word. The combination of a high average OU score plus the low residual tells us that students both understand this word accurately and that are aware that they know it.

In contrast, the sum of scores plot in Table 1 for the word 'succinct' suggests that it was not a word that was well-known to most participants. Interestingly, it has a lower residual when compared with the other words as well. This is because 38% of the participants had an OU = PU value that was zero. So, although the lower residual suggests an accurate self-assessment (high correlation between OU and PU), the unclustered distribution of its scatter-plot suggests it is a particularly inaccessible word for most students. Additionally, this case illustrates that the residual, OU/PU ratio, sum of scores graph and scatter-plot should be considered together to formulate a more complete understanding.

We also investigated the statistical significance by performing an ANOVA on the mean of the OU score and PU score for each word, as seen in Table 2. The results show that 'bonnet', 'bungalow' and 'fax', and to some degree 'Jell-O' (which just misses the threshold of $p = 0.05$), are self-assessed accurately. However, the other words are not. Table 2 shows the means and standard deviations for the OU and PU scores, as well as the difference between the two, and the t-test results for each word. It is interesting to note that 'Jell-O' is not included in the list of accurately self-assessed words when using this method, even though the scatter-plot in Table 1 might indicate otherwise. It is clear that the cultural terms we tested had the least variability in OU/PU ratio, and the highest OU/PU values. In addition, the distribution of scores on the scatter-plots for the cultural terms shows that many students are unfamiliar with these terms, but they recognize this lack of familiarity; it is visible to them. These results appear to indicate that students more accurately assess their understanding of cultural words, or at least this small subset of words.

The results for linguistically-difficult and technical words are more complex. The OU/PU ratio and residual values for linguistically-difficult words are relatively consistent. The OU/PU values, for example, fall in a relatively narrow range from 0.65 to 0.76, which is lower than the values obtained for the cultural words. This indicates that students are consistently unaware of their misunderstanding of these words. The technical words, by comparison, show far less consistency. There seems to be no clear trend for the technical terms, some are very well understood and accurately self-assessed, such as 'fax' and 'mold'. While 'tolerance' had a surprisingly low degree of understanding and the level of understanding was poorly self-assessed. It will require further investigation involving more words, ideally evaluated in context, to fully characterize the issue particularly for technical non-course-specific terminology.

In this study, we found that students are typically better at self-assessing their understanding of cultural words and had difficulty assessing their understanding of linguistically-difficult words. This suggests that cultural and perhaps even technical words are more often visible barriers to accessibility, while non-course-related linguistically-difficult words may more often represent invisible barriers. That is, students may not seek clarification of a linguistically-difficult word because they incorrectly believe they have a sufficient understanding of the word. This type of invisible barrier has an analogy in misperceptions of basic physics concepts (which have been studied extensively, e.g. the force concept inventory), or other pre-existing misconceptions, which need to be taken into account to make instruction effective. These conclusions are limited, however, by the words that were used in this study. A more extensive investigation, particularly examining the understanding of words in context, would be needed to fully elucidate this issue.

It is important to note that the scope of this study limits the generalizability of the data. Specifically, we cannot confidently predict whether misunderstanding a specific term can inhibit overall learning and the student's ability to succeed on assessment measures. Although making such claims might sound intuitive, this data is limited and there is little additional data in the literature to support such a claim. Further research needs to be performed.

5. Discussion

We can draw some preliminary conclusions from this study that should be tested further. From our observations in the classroom, we find that language can be a barrier to accurate assessment of learning for some students. This study indicates in a very limited way whether these barriers are visible or invisible to students in the form of ten words. Although this study is just a small element in the larger investigation of inaccessible language, this study informed preliminary data about how students perceive their understanding of ten words found in engineering exams. We found that all of the words tested were unfamiliar to some degree: no term had an average observed-understanding score above four. As expected, the findings illustrate that students do not understand colloquial language identically. We also found that these students did not accurately self-assess their understanding of such words consistently. Perceived-understanding scores were consistently higher than the observed-understanding scores. This shows that these students tended to over-rate their understanding of colloquial words and this appears to be especially true for linguistically-difficult words. This consistent over-rating is an example of a learning barrier that students are unaware of; it is an 'invisible' barrier to learning. This information can help us create techniques that assist in vocabulary clarification to reduce these learning barriers.

The existing literature on accessibility is extensive and spans across several disciplines including equity, disability, gender and, among others, higher education studies [9]. This literature helps to explain why language is integral to an inclusive learning environment [8]. Specifically, the fact that learning barriers exist in the language of engineering course materials may be one reason why students (especially first-year students) find it challenging to adjust to an environment that appears to be culturally foreign [10]. The finding that cultural language is a visible barrier might be why students often attribute this alienation mainly to cultural-acclimatization. We may be underestimating the role of invisible language barriers, such as the use of linguistically-difficult words. Specifically, our findings suggest that it would be worth investigating further the impact of these invisible language barriers on inclusivity.

Some work in the field of composition studies appears to link vocabulary and related issues to educational discourse, and may inform a promising approach to such further investigation. Specifically, Bartholomae's seminal work has led to further exploration of how language can create a barrier to learning [11, 12]. For instance, learning how to write like an 'expert' may produce barriers if the student is not confident in his or her current writing style; further research shows how individualized approaches to language and vocabulary in the classroom may interfere with what is considered 'correct' in that field. Though integral to learning about language in academia, our study at-present has a limited scope pertaining to self-efficacy in accurately identifying understanding ten words in engineering examinations. In addition, our study is to test whether students can use this information to gauge their understanding of these words; further discourse into composition studies and related fields is very useful, albeit out of the scope of this particular study.

While both visible and invisible learning barriers hinder student success, this study might hint that a UDE approach such as word lists posted prior to an exam may be useful as a mitigation technique, particularly for some types of words. Since students are likely to accurately self-assess their understanding of colloquial-cultural language, word lists of cultural terms may be an effective mitigation strategy for this particular type of learning barrier. However, this is a very preliminary study of the situation, and a more thorough investigation can provide a more complete picture of the issues. In addition, our results suggest that such word lists may not be as useful for technical and linguistically-difficult words. Linguistically-difficult words, in particular, are different because they often appear to be invisible barriers to understanding, which suggests that these words need to be identified as unfamiliar before word lists can become an effective tool. Additionally, this mitigation tactic continues to assume that students can independently learn the meaning of words once they are aware of their lack of understanding. The principles of UDE provide guidance on creating a more accessible learning environment, but further study is needed to identify how UDE can be used when the barriers to accessibility are invisible to the student.

This study is just a first step in elucidating the issues that arise with the contextualization of problems in engineering learning materials. We need to better describe the vocabulary that is presenting difficulty for our students, and then find methods for dealing with these barriers. One way of possibly alleviating language issues is to develop tools (e.g. software) that explicitly identify inaccessible language for both the instructors and the students. This would allow the participants in the learning environment to personally choose how to mitigate the potential barriers. Our future work will also consider learning barriers in engineering more broadly: Taber's typology of learning impediments can potentially be a starting point for this research [11]. Ideally, confronting these issues using a UDE-based approach increases accessibility for everyone, not just those identifying cultural words as a learning barrier, since both the instructors and students benefit from a more valid assessment.

6. Conclusions

From this study we have learned that colloquial language as a learning barrier can be characterized along a spectrum from visible to invisible, the types of words that can be classified into each of these categories, and that we can use this information to develop possible mitigation tactics. Within the context of ten words, our results show that each undergraduate engineering student views and understands colloquial language uniquely, differently from each other and from the instructor. Further, the accuracy of self-assessing one's understanding of inaccessible language is determined by the visibility of the learning barrier itself. These inaccessible terms can be roughly classified into colloquial-cultural, technical, and linguistically-difficult language; only the first appears to be a *visible* inaccessibility for students, according to our dataset. To mitigate potential effects of using colloquial-cultural language in exams, we suggest that the use of word sheets containing these terms might be effective while promoting a UDE approach to instruction. To reduce inaccessible vocabulary, the author's future work includes broadening the scope of this study to a larger corpus of language, then analyzing and developing a software-based approach whose interface suggests accessible alternatives for identified visible and invisible language issues on engineering assessment instruments.

Acknowledgment—The authors gratefully acknowledge Professor Mark Chignell for his input on computational methods and for the participants of this study for their time.

References

1. North Carolina State University Center for Universal Design, http://www.ncsu.edu/project/design-projects/udi
2. W. L. Wilkoff, and L. W. Abed, *Practicing Universal Design: An Interpretation of the ADA,* Van Nostrand Reinhold, New York, 1994.
3. Americans with Disabilities Act of 1990, P.L. 101-336, 104 Stat. 327, 42 U.S.C. 12101 *et seq*.
4. Telecommunications Act of 1996, P.L. 104-104, 110 Stat. 56.
5. F. Bowe, *Universal Design in Education: Teaching Nontraditional Students*, Bergin & Garvey, Westport, CT, 2000.
6. J. M. McGuire, S. S. Scott and S. F. Shaw, Universal design and its applications in educational environments, *Remedial and Special Education,* 27(3), May–June 2006, pp. 166–75.
7. S. M. Pliner and J. R. Johnson, Historical, theoretical, and foundational principles of universal instructional design in higher education, *Equity & Excellence in Education,* **37**(2), 2004, pp. 105–113.
8. C. Variawa and S. McCahan, Design of the learning environment for inclusivity, *Proceedings of the 2010 American Society for Engineering Education Annual Conference and Exposition,* Louisville, KY, June 20–23 2010.
9. L. C. Brinckerhoff, J. M. McGuire and S.F. Shaw, *Postsecondary Education and Transition for Students with Learning Disabilities*, Pro-Ed, Inc., Austin: TX, 2002.
10. D. Trytten, A. Lowe and S. Waiden, Racial inequality exists in spite of over-representation: The case of Asian American students in engineering education, *Proceedings of 2009 American Society for Engineering Education Annual Conference and Exposition*, Austin, TX, June 14–17 2009.
11. D. Bartholomae, Inventing the university, *Journal of Basic Writing,* **5**, 1986, pp. 4–23.
12. A. Johns, *Text, Role, and Context: Developing Academic Literacies*, Cambridge University Press, New York, 1997.
13. K. S. Taber, The mismatch between assumed prior knowledge and the learner's conceptions: A typology of learning impediments, *Educational Studies,* **27**(2), 2009, pp. 159–171.

Chirag Variawa is a Ph.D. Candidate in the Deparment of Mechanical and Industrial Engineering at the University of Toronto. He earned his B.A.Sc. in Materials Science Engineering in 2009 from the same institution. His multi-disciplinary research uses principles from artificial intelligence, computational linguistics, higher education and aspects of neuroscience to investigate the design of engineering learning environments.

Susan McCahan is an Associate Professor in the Department of Mechanical and Industrial Engineering at the University of Toronto. She received her B.S. (Mechanical Engineering) from Cornell University, and M.S. and Ph.D. (Mechanical Engineering) from Rensselaer Polytechnic Institute. Dr McCahan has held several administrative positions including Chair of First Year in the Faculty of Applied Science and Engineering at the University of Toronto, and was appointed to the position of Vice Dean Undergraduate in 2011. She has taught a first-year design and communication course (enrolment: ~950 students) since 2003.