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Universal Instructional Design Applied in a Design Classroom

Abstract

One of the major challenges in teaching large courses is the diversity of the student population. Characteristics now common in undergraduate engineering student populations include diversity in learning style, cultural background, and factors that may disadvantage students, such as a learning disability. One approach to addressing these challenges is Universal Instructional Design (UID) and it is now gaining acceptance in higher education.

The principles of UID were originally developed by analogy with accessible design in architecture and product development. One of the interesting aspects of discussing UID in the context of design education is that it demonstrates the impact of design methodology in fields beyond engineering. In addition, because of some of the special aspects of engineering design courses, the UID principles lend themselves to application in this type of learning situation. These principles have been applied, with observable outcomes, in a large (enrolment ~950) first year design course to improve the accessibility of the content.

Design for Accessibility

Tracing the development of Universal Design, or design for accessibility, and its impact on architecture, product design, and infrastructure design gives us insight into what benefits, intended or unintended, may arise when we apply these principles in the classroom. In addition, as design instructors, it is useful as a lesson on the way in which social movements and ideas transferred from field to field inform, or reinvigorate, an area of practice in engineering.

The concepts of design for accessibility began to take hold in architecture, particularly for the design of public buildings, in the 1970's. These principles form the foundation for legislation enacted in the United States and elsewhere.[1] The implementation of legislation, such as the Americans with Disabilities Act, led to a change in building requirements intended to make buildings more accessible to people with physical disabilities.

The requirements of accessibility can be viewed as a design constraint. Simplistically, there are two approaches to dealing with such a constraint. The structure could be designed first, and then features which make the structure accessible could be added on or, more advantageously, the design could begin with accessibility as one of the primary functions of the building and thus harmoniously integrate functionality and aesthetics. The second approach was pioneered by Ronald Mace and others at The Center for Universal Design (North Carolina).[2] The Universal Design concepts developed by Ronald Mace have led to innovation in a number of fields. In information technology, it led to US legislation affecting the features of consumer products[3] – for example, the requirement that televisions include closed captioning capability. The principles have also found their way into other types of product design.

"The Human Factor" by K. Vicente[4], and related research work in the area of human factors engineering, documents the shift in design from a "one size fits all" approach, i.e. the user should conform to the product, to a "one design accessible to all" approach, i.e. the product should adapt to the user. The idea of human factors was certainly not new to engineering, or product design. However the impetus in architecture, combined with several other social and historical forces in the 1970's and 1980's to create somewhat of a renaissance in this field. Some of the other movements occurring which contributed to this were: the opportunity to broaden the market for technology devices (e.g. computers) beyond the science and engineering workplace thus creating the need for "friendly user interface" design; the movement to "mainstream" people with disabilities and their call for equal access to public services; and, more recently, the aging population demographic in the United States.

Concurrent with the development of the concepts of Universal Design was recognition of the unintended benefits of this approach. These include economic benefits, flexibility, and inclusivity. It is useful to briefly discuss these benefits because of the analogy between Universal Design for products and systems, and design of educational units, such as courses.

There are a number of economic benefits to Universal Design. First, accommodating special needs with unique services is expensive. Consider, for example, the public transit system in Toronto which is currently only partially wheelchair accessible, necessitating a public "Wheel Trans" service which individually picks up and transports people in specially equipped vans. Wheel Trans will always be necessary, because there will be people who can not use public transit even if it is fully wheelchair accessible. However, increasing the accessibility of the "mainstream" service decreases the load on the Wheel Trans service, which consequently decreases the overall cost of the system. Making an adaptive service or feature available in a consumer product has a similar economic result. The cost of providing a feature, such as closed captioning on televisions, is expensive if it has to be bought as a special feature, but when it is included as a standard feature of the product the cost typically drops by several orders of magnitude.[5] Second, though retrofitting is economically beneficial, retrofitting a system or building after the fact to make it accessible is generally far more expensive than designing accessibility into the system in the first place.

Universal Design is flexible. Features which make a design more accessible can also be used or adapted for use by a person who does not have the exact disability for which the design was originally intended. For example, people pushing children in strollers would not necessarily be considered "mobility impaired". However, they can make use of the accommodations that have been designed into public systems for a person in a wheelchair. It is far easier to get a stroller down to a subway platform by elevator than it is to carry it down a set of stairs. This is one example of flexibility of use, and examples of this abound. Information technology provides particularly interesting case studies of this phenomenon. For example, text messaging, originally designed for people who are hearing impaired, has become a pervasive means of communication in our society because it is flexible (i.e. can be used by people regardless of their level of hearing).[5]

Similarly the principle of inclusion is one of the primary concepts in Universal Design. The idea that to the greatest extent possible people of all abilities should be able to use the same system is an important equity issue. For example, for aesthetic or practical reasons buildings will sometimes have the "accessible" entrance at the back. This design then requires a person who has difficulty climbing stairs to go around to the back door to enter the building. This requires extra effort, and there are socio-cultural connotations related to entering through the back door. The back door may be physically equivalent but carries social meaning that stigmatizes the user. So in this example the very act of separating someone from their peers and requiring them to access the system differently creates an additional effort and a disparity that must be considered a design flaw. The system designer needs to be cognizant that such disparities can arise if accessibility, in its fullest form, is not explicitly recognized as one of the basic goals in the design process. If we intend our designs to be bought and used by the widest possible user set then we must make each of our intended users feel that the system, product, or service was designed with them in mind; to meet their physical, psychological, and social needs.

Taken as a whole we conclude that stakeholder concerns, in this case the needs of our diverse user population, force us toward creative designs that are better in terms of economics, flexibility, and functionality, than what we might have developed otherwise. And it is this concept, which was developed first in architecture and then migrated to product design, that is now being articulated for instructional design. When we open up a system to a more diverse user group: The system at first has barriers to accessibility; then evolves retrofitted elements to accommodate the new group; and eventually new designs are developed with the expanded user group already accounted for in the core user population. The resulting system is improved for all users by these additional considerations in the design process, and the design takes on an integrated quality, i.e. the "accessibility" elements are inherent to the design.

Principles of UID

The concepts which underlie Universal Design have been adapted into a set of principles for Universal Instructional Design (UID). UID is essentially synonymous with Universal Design for Instruction, or Universal Design for Learning, other terms that can be found in the literature. Several authors have published versions of the principles.[5,6] Pliner and Johnson[7] summarize the principles articulated by Scott et al.[6], as follows:

1. Equitable use—making classroom material accessible to diverse learning needs and styles
2. Flexibility in use—the practice of using a variety of instructional methods
3. Simple and intuitive—teaching "in a straightforward and predictable manner''
4. Perceptible information—ensuring that course material is accessible to students regardless of their "sensory abilities''
5. Tolerance for error—building diversity of learning "pace and prerequisite skills'' into course process
6. Low physical effort—designing instruction "to minimize . . . physical effort'' so that students can attend to essential learning
7. Size and space for approach and use—engaging the classroom space in ways that addresses diverse student needs based on "body size, posture, mobility, and communication''
8. A community of learners—teaching and learning environment supports and encourages "interaction and communication among students and between students and faculty''
9. Instructional climate—all students are encouraged to meet "high expectations'' as they are "welcomed'' to participate in the course.

A good discussion of these principles can be found in Pliner and Johnson[7] and, in more detail, in Bowe[5].

My interpretation of principle 5 is slightly different than Scott et al. The "tolerance for error" principle developed out of a similar principle in Universal Design that is particularly applicable to information technology; the idea that hitting the wrong button should not have catastrophic results. Software, for example, will now typically ask you to confirm a choice before proceeding, e.g. confirming you want to delete a file. In a learning environment, I would suggest that "tolerance for error" means that a student's course mark should not be substantially affected by a single minor error, or hinge on their first time performance of a task.

In fact, the UID principles list can be seen from a broader viewpoint as general guidelines for good teaching practice. As with Universal Design in architecture, making a system accessible in accordance with a guideline set of this kind has the benefit of improving the system for a broad population. It is also the case that our student population has diversified tremendously in the last 40 years. We have a growing number of students with learning disabilities. In addition, diversity in the areas of age, ethnicity, and cultural background have all increased. In my classroom, it is difficult to identify a "typical" student. We have always had classrooms full of students with individual needs, but the population of students today has a degree of diversity that was not accounted for in the design of our engineering educational system which dates back to the 1960's.

Currently, most universities are in the "retrofit" phase of accessibility implementation. That is, rather than re-designing the system for accessibility, we are keeping the old system that works reasonably well for most of our students and providing special services for students with special needs. As the population of students with special needs is growing, the cost of this approach is increasing. For example, in 2004/05 at the University of Toronto our Accessibility Services office coordinated accommodations for 1333 students, about 2 % of our student population, who have an on-going need.[8] This does not include students who have a temporary disability (broken arm, etc.), which is another population that requires special services. The number of students registered with this service on campus has almost doubled since 1999/00.[8] As this cost increases, the pressure on the system for radical re-design will intensify. This number also demonstrates that there is already a substantial population of students who need a re-designed system not as an enhancement of a good educational experience, but simply in order to access the system.

The principles of UID were originally devised to address accessibility for students with physical and learning disabilities, and much of the literature on the subject is for K-12 children with special needs. However, there is a growing body of literature on the applications of UID at the university level.[5,6,7] Furthermore, these concepts are being extended to a wider range of diversity which is now present in the engineering student population.[5] If our experience from Universal Design of products carries over to education, then the overall effect of designing courses using the UID guidelines will be an enhanced learning environment for all students.

Example of Implementation

Large courses present excellent opportunities to try out UID. Courses of this nature have a diversity of students. It is often possible to provide extra features that would not be possible in a small course because of resource limitations. And the effect of having an accessible course has a substantial impact both in terms of an enhanced experience for a large number of students, but also in terms of the reduction in "special accommodation" costs.

At the University of Toronto there is a freshman design and communications course in engineering which has an enrolment of approximately 950 students. The course, "Engineering Strategies and Practice" (ESP), was piloted in 2003/04 and has been in full scale implementation for two years. The design of the course essentially adheres to the UID principles. However, during the pilot phase, a number of barriers to accessibility were identified. In the evolution of the course to its full implementation, these barriers have been addressed and we are continuing to examine and evaluate the accessibility of the course.

Vocabulary

Barriers associated with vocabulary were identified as recurring issues during the pilot phase of the ESP course. In this context "vocabulary" refers to words, and also to meanings of phrases. Frequently questions on engineering problem sets or tests are set within a relevant context. This is considered good practice for a number of reasons, such as providing motivation for the material, and testing whether the student can transfer understanding from the abstract to a practical situation. In design courses, contextually based problems are prevalent. However, this practice can present a barrier for students when they understand the material, but are disadvantaged by the context. We have found that one of the major barriers to comprehension is vocabulary. The difficulties do not generally derive directly from the student's English fluency, but rather from a difference in the working vocabulary, cultural references, and experiences between the student and the instructor who created the exam or assignment.

Consider the following four examples:

1. "You are to design a banana slicing device for a new chain of restaurants that will serve only peanut butter and banana sandwiches. A standard banana must be sliced into 20 slices, each 6 mm thick…." (taken from a quiz in ESP)
2. "Instead of using a singular distribution of vorticity in two-dimensional computations, a "blob" with a Gaussian distribution is sometimes chosen.…"[9] (taken from a graduate level exam question)
3. "Consider the heat transfer through a framed wall. The wall materials are shown in Fig. 1 below. The 2x4 framing is 16" on center, and the area between the 2x4's is not insulated (can be considered air space)…" (adapted from a problem set created by the author for a senior level mechanical engineering elective course)
4. "Assuming that you were trying to determine the environmental impact of a proposed new petrochemical refinery, which of the following would you NOT likely include on your list?

   (a) workplace safety
   (b) toxicology of materials…"
   (taken from a test in ESP)

Each of these examples represents a different type of barrier, and it is worth understanding the differences before discussing an approach for overcoming these issues.

In example 1, the question implies a familiarity with a food that is highly culturally specific. A student who had watched their parent make this sandwich, or had made one themselves, would have an advantage in quickly understanding the issues involved in the slicing process relative to a student who was completely unfamiliar with this. This is an example where the instructor has assumed that his students have the same cultural references as he does. This is not an insurmountable hurtle for a bright student, but it may put the student at a slight disadvantage and clearly the question presents a problem with respect to inclusivity. The question suggests an expected audience that would not include the majority of our students.

Example 2 illustrates a gap between the instructor's colloquial vocabulary and that of their students. It also demonstrates that this type of hurtle is not confined to qualitative questions, but can arise in technically oriented contexts. The word that presented difficulty was "blob". The students who brought this to my attention were fully fluent in English, but spoke a different language in their home environment. They had no difficulty with the "high level" technical language in the rest of the question, but the word "blob" was outside of their working vocabulary. Both of them spent a considerable amount of time (independently) on this take home exam trying to find the technical definition for blob, only to realize that it was not a technical word. Relative to me and others in the class, this clearly put them at a distinct disadvantage on this time-limited exam, although the issue had nothing to do with their understanding of the technical material.

In example 3 the instructor has assumed a piece of pre-existing "technical" knowledge that most of the students lacked: the actual dimensions of a 2x4. The figure that went with the question showed the structure of a framed wall, and illustrated the meaning of "16 inches on center". However, nearly every student in the class got the wrong answer to the question. Moreover, the thermal resistance of a 3.5" air space was readily available (it was in the textbook), but many students spent valuable time extrapolating to get a value for a 4" air space. In this case the barrier was the result of a discrepancy between the general knowledge base assumed by the instructor and the actual knowledge base of the students.

Example 4 includes a term, "toxicology", which is not a colloquial word, but which we might expect most adults with an engineering degree should know. Normally if this word appeared on an exam we would expect to get a substantial number of questions about its meaning. While the word is within our "professional vocabulary" as instructors, it would not generally be a word that all of our first year students would be expected to know, and thus could present a barrier to comprehension for our students. Interestingly, in a class of approximately 950 students, we had virtually no inquires concerning this word although the question shown in example 4 appeared on a final exam in ESP.

When the question shown in example 4 appeared on the final exam we had implemented an idea for addressing the vocabulary barriers that have just been discussed. About a week before the exam we published a vocabulary list for the students. The list is compiled from a draft of the exam. We make it clear in the introduction to the list that it is not exhaustive; they may see words on the exam that were not on the list. It includes all of the words, and phrases, that may present difficulty for some students using the following guidelines:

- The list includes colloquial words that may not be familiar to a student who has been through many years of school in English, but who speaks a different language at home. So we would include words such as “ant”, “hill”, “kettle”, “spatula”, “blob”, etc.
- The list includes a number of other words and phrases that will not appear on the exam but which we think all engineers should know, for example: propagation, assembly, Environmental Protection Agency.
- The list does <u>not</u> include basic words such as “under”, “over”, etc.
- The list does <u>not</u> include words or phrases that are “course concepts”. So we would not include the phrase “life cycle analysis” because this was a concept taught in the course.
- The list does <u>not</u> include definitions.

For a typical midterm or final exam the list consists of approximately 150 to 200 words and phrases. Most of our students find that only a few of the words are new to them. We are in the process of investigating this qualitatively to understand how large the gap is between our vocabulary and that of our entering students.

The vocabulary list fulfills a number of UID principles. First it is equitable. All students have access to this list and access it in the same way. We do not try to identify students who need special help with their vocabulary and only address their needs on an individual basis. In terms of flexibility, the list is posted on-line and can be used in a variety of ways. It becomes the student’s responsibility to make sure that they review the list before the exam and know the words. We do not specify how they understand the words. Requiring students to memorize definitions for all of the words, for example, would be counterproductive. The list is simple and intuitive to use and can be accessed using a screen reader if the student would rather listen to it than read it.

As in other Universal Design examples, this approach has had a number of beneficial consequences outside of its original goals. There has been a reduction of questions from students during the exam. Questions during the exam are problematic, particularly in a large course where the students are spread out over several rooms during the test. Responses to the same question may vary from room to room based on the teaching assistant who is invigilating, which impairs consistency. Our teaching assistants are now trained not to answer any question concerning the meaning of a word on the exam, but we have few, if any, questions of this nature at the final exam anymore.

We have also hypothesized that the list leads to a reduction of anxiety for students. We plan to investigate this further, but it appears that students who have exam anxiety feel a reduced sense of stress when they are able to see in advance the words that will appear on the exam. It may also be beneficial for students with learning disabilities because it gives them time to familiarize themselves with the words in advance.

Perhaps one of the most useful aspects of the list is that we can now word questions on the exam using the precise language we want to use without regard to our students’ current vocabulary abilities. In the past we would have been reluctant to use a word such as “toxicology” on a freshman exam, even if this is the word that best fits the meaning we wanted to convey. Using the vocabulary list, the exam is constructed using language that is appropriate for the discipline and specific. Although an increased vocabulary is not one of the explicit objectives of the course, it becomes an implicit result.

The vocabulary list, while not high-tech or particularly exciting, has had a positive impact for our students. 56% of the students who said they read it reported finding it somewhat to very useful on a survey at the end of the term. This can be compared to the statistic that approximately 40% of our students report that English is not the language used in their home environment, so clearly there is a proportion of "English as a first language" students who find that accessing this list is useful. The vocabulary list idea could be used in any class to enhance accessibility. In a design course it is particularly appropriate because the contexts in which we set our questions tend to be broader than a typical technical course such as calculus for instance.

iWrite

One of the other primary examples of a tool used in ESP that conforms to the UID principles is iWrite.[10] iWrite was incorporated into the ESP course because we repeatedly received comments from the students indicating that the instructions for the writing assignments in the course were "unclear". The instructor team working on the course had tried very hard to develop very clear instructions and we had provided supplementary material which further explained specific elements of the assignments, such as how to write an executive summary. Despite the additional material, the open-ended nature of the assignments which require critical thinking and writing skills, were creating a high level of discomfort and frustration for our first year students.

Developed at the University of Toronto, iWrite is an on-line tool for helping students with their writing. It is customized for the course and gives students an alternative method of accessing assignment instructions. iWrite consists of two parts: a set of commented examples for students to look at and a "prompt set" for each assignment in the course. It is the prompt sets which particularly pertain to UID concepts.

The assignments in ESP, because it is a design and communications course, are documents that pertain to the design process. For instance, a typical assignment would be a progress report to a client which includes sections such the problem definition statement; regulations and standards that apply to the design; alternative design concepts that were considered; human factors considerations; etc. When the instructions for the assignment are posted, we also open up the corresponding prompt set in iWrite.

In iWrite the instructions are re-interpreted as a set of questions for the student to answer in text boxes on-line. To illustrate: the written instructions may require that the student include an executive summary in their report. The written instructions would also include a brief explanation of the expected content in an executive summary, and there is information on this in the course textbook as well. In iWrite the first 3 prompts read:

Step 1) List sequentially ALL of the major sections and/or points that are contained in your document.

Fill in answer here

Step 2) For each of the items in the list above, cut and paste here the most important sentence from this section (or point).

Fill in answer here

Bear in mind that this is a good way to start but is not sufficient to create a good executive summary.

Step 3) For each sentence (or point) pulled from the document, add one or two sentences (or points) that support (provide evidence) for the idea. The purpose here is to make the ideas you present in the Executive Summary credible.

Fill in answer here

The iWrite prompts are a simple means of providing flexible access to the assignment instructions (UID principles #2, 3, and 4). This multi-modal approach may work with the student's learning style. It would be interesting, for example, to examine whether global learners prefer the standard instructions and sequential learners prefer the iWrite prompts. At the end of an iWrite session the student can email their responses to the prompts to themselves and this serves as a first draft for the document. The prompt sets are available independently for each section of the document and are given in a fairly general form, as shown in the example above. The student can then re-use this prompt set every time they need to include an executive summary in a document, regardless of the particular assignment. The intention is to make the learned process of writing a section such as this transferable to other contexts. The iWrite prompts serve as a scaffold. We also found, from comments on the course bulletin board, that students sometimes used the prompts to give them a different perspective on the instructions, rather than actually working through the steps. Interestingly, one of the unintended results of the iWrite prompts is that it forces the instructor to consider very carefully exactly what their expectations are for a particular assignment.

In a class survey, 90 to 96% of the students reported using iWrite either to look at the samples or to use the prompt sets or both (see data in Table 1). The posted samples were clearly of more interest to the students. However, a substantial percentage of the class also used the prompt sets for their assignments.

Table 1: Data on iWrite usage from ESP I end of term survey.

Year	2005	2006
Number of responses	648	696
I only reviewed the iWrite samples	42.7%	46.8%
I only used the iwrite prompts	5.7%	5.5%
I used both the samples and the prompts	45.7%	37.5%
I did not use iwrite	5.9%	10.2%

It should be noted that no matter how the student chooses to access the assignment instructions, the expectations for the assignment remain the same. This is one of the key points of UID. While giving the student a number of approaches to the material, the learning objectives are not compromised and the integrity of the course is maintained. The steps provided in iWrite do not bypass critical thinking, but instead prompt, or guide, the thought process. The scaffold should be denser in freshman year and gradually be removed as the student gains the ability to fill in their own structure. Overall, the use of iWrite, and tools like it, are analogous to a ramp. The learning experience is enhanced, but the student still needs to demonstrate mastery of the required material in order successfully complete the course.

Conclusion

The examples of iWrite and the vocabulary list demonstrate elements that can make a course more accessible for students from different cultures or with different learning styles. The use of these tools was particularly supportive in a first year design course. The vocabulary list helped us to address the barriers that arose from putting design questions in relevant context on the tests. And iWrite created a useful scaffold for learning to approach open-ended assignments of the type that are particularly common in design courses. The data collected from the students indicates that both of these tools were used widely by the class. Although these types of tools can certainly be created in the absence of an understanding of the UID principles, the principles assist us in understanding why the tools are effective, how they can be made more effective, and can suggest what other changes to the course design could improve its accessibility. Overall, the migration of Universal Design strategies from architecture and engineering to education demonstrates the broad impact of design methodology and suggests that a grounding in this methodology serves our students whether they decide to stay in the profession or move into other fields for their careers.

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