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ABSTRACT

This paper examines how teachers, as educational designers, can utilize universal design for learning (UDL) concepts. UDL is a comprehensive approach to the design of educational systems that addresses elements necessary for the achievement of desired educational goals and objectives: elements such as equity among the participants, environmental supports, and the coupling between participant abilities and task requirements. The essential principles of UDL, which work synergistically, are: equitability, ergonomic soundness, perceptibility, cognitive soundness, error management, flexibility, and stability/predictability. The UDL principles presented in this paper draw from Enabling Technology Laboratory experiences as well as the knowledge and experience of many individuals, ranging from educators to engineers. Educational designers can systematically apply UDL principles to create more efficient and effective educational environments. (Contains 15 references, 1 table, and 7 figures.) (Author)

Universal Design for Learning: Curriculum, Technology, and Accessibility

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Abstract: This paper examines how teachers, as educational designers, can utilize universal design for learning (UDL) concepts. UDL is a comprehensive approach to the design of educational systems that addresses elements necessary for the achievement of desired educational goals and objectives: elements such as, equity among the participants, environmental supports, and the coupling between participant abilities and task requirements. The essential principles of UDL, which work synergistically, are: equitability, ergonomic soundness, perceptibility, cognitive soundness, error management, flexibility, and stability/predictability. The UDL principles presented in this paper draw from Enabling Technology Laboratory experiences as well as the knowledge and experience of many individuals, ranging from educators to engineers. Educational designers can systematically apply UDL principles to create more efficient and effective educational environments.

Introduction

Teachers commonly refer to their preparation work as "lesson plans". Yet what they are really doing is design work: they are designing educational activities, materials, and curricula. Thus, teachers are educational designers. As such, educational designers have one simple goal: to create the best possible design. Universal design for learning is a conceptual approach that enables educational designers to more fully realize that goal.

Universal design for learning (UDL) is a comprehensive approach to the design of educational systems that addresses elements necessary for the achievement of desired educational goals and objectives: elements such as, equity among the participants, environmental supports, and the coupling between participant abilities and task requirements. The application of UDL principles targets the educational needs of all students while addressing different learning styles. Truly *every* student, from the gifted to the at-risk to the one with physical and cognitive disabilities, benefits from UDL. Technology plays a pivotal role in these endeavors by enabling increased adaptability and flexibility. The International Technology Education Association states that technology is "the diverse collection of processes and knowledge that people use to extend human abilities and to satisfy human needs and wants" (ITEA, 2002).

UDL builds on universal design principles developed by architects and engineers, but goes on to add principles gleaned from psychology and educational research. UDL strives to create environments, educational materials, and activities that are more physically and cognitively accessible. Physical accessibility includes wheelchair accessibility and computer access through the use of assistive technology such as alternative keyboards or screen readers. Perceptual accessibility includes dealing with disabilities such as color blindness, hearing loss, or visual impairments. While the distribution of IQs associated with cognitive disabilities must be considered, cognitive accessibility is not limited to individuals with disabilities. UDL must also include the creation of materials that support different learning styles and strengths, providing students with multiple ways of engaging the material, presenting material, and reporting results. In short, UDL should be regarded as simply *good design* practice.

The movement toward universal design has world-wide following. In the United States IDEA 97 (the 1997 amendments to the Individuals with Disabilities Education Act) is a major impetus for utilizing universal design principles in education, in that it mandates a fuller inclusion of individuals with disabilities in general education classrooms and activities. In a recent resolution the Council of Europe, Committee of Ministers, state the need to integrate people with disabilities into the community using universal design or "design for all" principles. Education was one of the specifically mentioned areas of need (Council of Europe, Committee of Ministers, 2001).

The European Concept for Accessibility Network makes the case for equating universal design with good design. In discussing diversity in the years 2000 and beyond they urge Europeans to "no longer talk about the specific needs of certain categories of people, but talk about human functioning. We should look at every aspect of human functioning, without categorizing. ... Accessibility will loose its stigma and become a mainstream issue. We won't need terms like Design for All or Universal Design anymore. We will only refer to good design and bad design" (European Concept for Accessibility Network, 2001).

The Enabling Technologies Laboratory (ETL) at Wayne State University embraces the definition of technology as "the diverse collection of processes and knowledge that people use to extend human abilities and to satisfy human needs and wants" (ITEA, 2002). This definition reinforces and supports the principles of universal design in that it allows technology to be not only devices, or things, but also processes, quality tools, and organizational/planning techniques. Through its partnership with eight southeastern Michigan Intermediate School Districts, ETL has worked with teachers to bring UDL applications into numerous classrooms. The UDL principles presented in this paper draw from ETL experiences as well as the knowledge and experience of many individuals, ranging from educators to engineers.

UDL Principles

The application of UDL should yield products and processes that are: equitable, ergonomically sound, perceptible, cognitively sound, error managed, flexible, and both stable and predictable.

Equitable: Educational products and processes should provide the same means of use for all users: identical whenever possible; equivalent when not. The products and processes should avoid segregating or stigmatizing any users, making the design appealing to all users (Connell, 1997). Figure 1 exemplifies this aspect of universal design. If a science classroom has binoculars available for field trips, then at least one of them should provide image stabilization.

Figure 1. An example of universal design. The binoculars contain microprocessor technology that stabilizes the image for all users. This allows a tired person or a person with tremors or other motor problems to use the same device.

Ergonomically Sound: The physical demands of educational activities must be within acceptable limits for a wide range of users. All individuals must be able to physically access the activity. Appropriate space for wheelchairs must be provided. The relative placement of materials, equipment, and users should be ergonomically sound. Students should be able to easily lift items, carry objects, turn knobs, press keys, and/or move computer mice; if they cannot easily perform such ergonomic tasks, alternative means of physical engagement must be available.

Perceptible: The product, system, and environment must effectively communicate necessary information to the user, regardless of ambient conditions or the user's sensory abilities (Connell, 1997). The design should utilize redundant modes of information presentation (e.g., verbal, iconic, pictorial, tactile). The design should maximize legibility by providing adequate contrast between the information and its surroundings. The expanded use of sound field systems exemplifies this principle. The teacher wears a cordless microphone and a portable amplifier/transmitter that transmits a signal to a receiver that then distributes the signal to speakers placed around the classroom. The sound field technology started in Special Education classes, but research shows that at any given time a high percentage of general education classroom students have hearing problems due to colds, flu, allergies, fatigue, and other temporary conditions (Crandell, Smaldino, & Flexor, 1999). Research also shows that students in sound field classes perform better academically than those not in such a class (Crandell et al., 1999). Hence, there is a growing trend to install sound field technology in all classrooms.

Cognitively Sound: The cognitive demands of educational activities must be within acceptable limits for a wide range of users. The task structure should be appropriate to the task – neither too wide nor too deep. The material must support different learning styles and human intelligences (Forrester, 2001).

Understanding the pivotal role of representations is central to the application of UDL principles. The educational material must provide different representations, which in turn appeal to different learning styles. Figure 2 shows a concept map illustrating habitats. This map was produced by a computer program that allows one to flip back and forth between a pictorial representation to a words-only outline form, thereby supporting different learning styles.

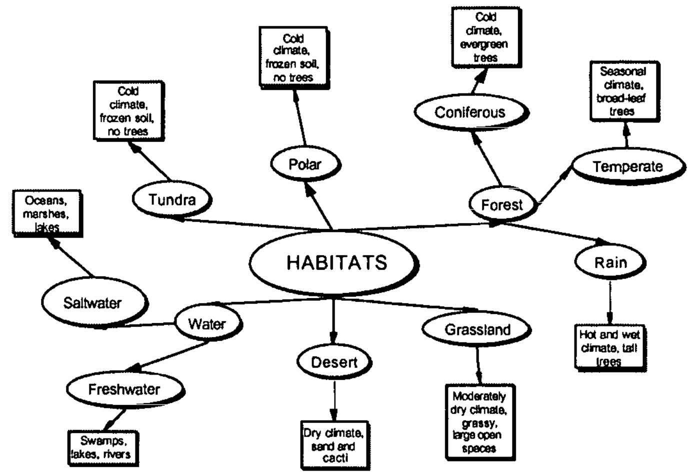

Figure 2. An example of a concept map illustrating habitats. This conceptual map was produced using Inspiration® a software tool to help develop ideas and organize thinking. A menu option allows the user to express the map in an outline form – words rather than images.

Creating appropriate representations of thoughts and concepts is also critical for reflection and discovering higher-order relationships. The process of a learner reflecting and forming ever more complex mental models of reality is central to the constructivist's learning theory (Jonassen, Peck, & Wilson, 1999). Educational designers use the laws of calculus to formulate, simulate, model, and test hypotheses concerning the physical behavior of elements. The ability to represent physical concepts such as force and electrical activity with mathematics allows us to analyze systems and design products. Graphs, charts, flow-diagrams, cause-effect diagrams, affinity diagrams, and conceptual maps are also examples of representations.

The representation should facilitate, not hinder, the reflective process of the learner. For example, Figure 3 shows two ways of representing numerical density data. The shading represents the data. In Row 1 there is no correspondence between the numerical density data and the visual shading density. In Row 2 the shading deepens as the numbers increase; thus, there is a relationship between the shading and the data. Row 2's shading is more intuitive than Row 1's shading because the visual shading becomes denser as the numerical density data it represents increases (Norman, 1993). The representation in Row 1 forces one to think about and compare the visual shading to the numerical data values; there is no natural mapping between the two representations. If the educational objective is to analyze the data and draw inferences about some physical process, then the extra cognitive processing introduced by Row 1's encoding interferes with learning.

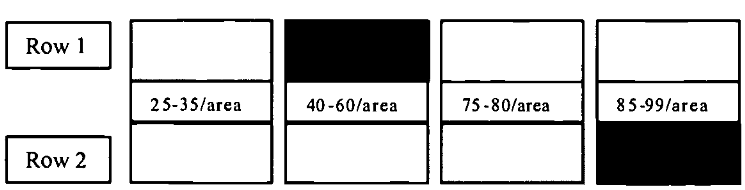

Figure 3. Example representations. The numbers represent some elements per unit area. Row 1's representation is less intuitive than Row 2's representation because in Row 2 the visual density increases as the numerical data density increases.

Flexible: The Center for Applied Special Technology (CAST) has formulated three principles that capture essential aspects of UDL in a simple and straightforward manner. Educators should provide students: 1) multiple means of representation, 2) multiple means of expression, and 3) multiple means of engagement (CAST, 1999). Multiple means of representing concepts, ideas, data, and information allow people with different learning styles or disabilities to more readily comprehend the essential concepts presented by the representations. Multiple means of expression provide people with a variety of ways to express themselves with respect to communicating, reporting, assessment, and evaluation. Lastly, and in some respects most importantly, multiple means of engagement enable people with different interests, learning styles, or disabilities to be more readily motivated to pursue and maintain engagement with the material. Motivation is a critical factor and, in that respect, providing multiple means of engagement is an essential element of UDL.

Flexibility is the key to providing multiple means of representation, expression, and engagement. Flexibility can be achieved in many ways across several dimensions. Table 1 presents five key dimensions of flexibility.

Table 1. Dimensions of flexibility as modified from (Collis & Moonen, 2001)

Dimension	Fixed ← element → Flexible
Time	Times for starting and finishing a course. Times for submitting assignments and interacting within the class. Tempo/pace of studying. Moments of assessment.
Content	Topics of the course. Sequence of different parts of a course. Orientation of the course (theoretical, practical). Key learning materials of the course. Assessment standards and completion requirements.
Requirements	Conditions for participation.
Instructional approach & Resources	Social organization of learning (face-to-face, group, individual). Language to be used during the course. Learning resources: modality, origin (instructor, learners, library, WWW). Instructional organization of learning (assignments, monitoring).
Delivery & Logistics	Time and place where contact with instructor and other students occur. Methods and technology for obtaining support and making contact. Types of help, communication available, technology required. Location and technology for participating in various aspects of the course. Delivery channels for course information, content, and communication.

Figure 4 demonstrates flexibility; it shows a student in an adjustable, mobile, seating system. When the student was provided with this seating system, rather than her wheelchair, her teacher remarked that she "was now part of the class." She could sit at the same tables, at the same height as her classmates. The student was excited and her classmates were also excited that she could now participate in classroom activities just as they could. (Also note that the seating system allows her to remain in her seating orthosis, which is critical for her ergonomic stability.) Thus, figure 4 exemplifies the UDL principal of flexibility because the special seating system enables this student to participate in "regular" classroom activities that were precluded when she is in her wheelchair.

Figure 4. Use of an agile device – a movable, adjustable chair made of Creform, a pipe and joint technology for creating agile devices. The student is out of her wheelchair and at the same level as her classmates, able to sit at the same tables.

Error Managed: Individuals learn by making mistakes; hence, UDL must manage errors. Educational activity associated with desired learning can be termed *value-added* activity. Activity not associated with the desired learning activity can be termed *non-value-added* activity. The non-value-added portions of the process must be error-proofed, while the value-added portion of the process must allow errors to occur (Erlandson, Greenwood, Perrin, & Zapinski, 1997). Figure 5 illustrates this idea for the educational objective of improving writing skills. The writing objective, inside the heavily outlined box, could just as easily be a computer program for mathematics or physics instruction.

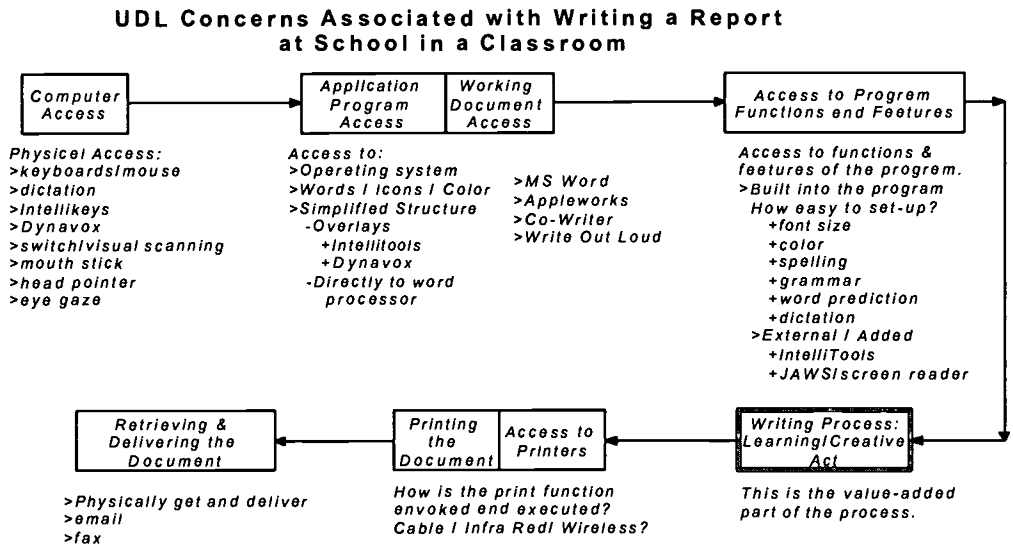

Figure 5. If the educational objective is to develop writing skills, the activities contained in the heavily outlined box, then everything outside the outlined box must be considered non-value-added activity. If students experience errors in setting-up or getting to the writing process, they may be so frustrated that they do not learn what is desired. If they experience errors and cannot print or otherwise obtain a copy of their work – this might also diminish the learning process.

Stable and Predictable: Educational environments need to be stable and predictable in that the learners, teachers, and other participants can expect an environment that supports the desired learning. A school classroom requires an environment different from a field trip, or community based experience. A metal shop will have different requirements than a library. The desired educational objective dictates what is or is not acceptable.

While each environment presents unique requirements for stability and predictability, a common theme across all environments is the need to reduce the inherent variability of the educational processes or activities that take place in the environment. The inherent variability of an educational process is not to be confused with providing variation and variability of curriculum materialor activities. These are very different conditions.

The reduction of the inherent variability of a process is a fundamental principle of universal design and key to the creation of stable, predictable systems. Every task and process naturally has a certain amount of variability or variance. Deming termed this variability *common cause* (Deming, 1982). Everyday occurrences, such as traffic volume and the timing of traffic signals, contribute to the time variability associated with one's drive to work. An accident or severe storm is an exceptional event that is not common to the process. Deming termed such events *special causes* (Deming, 1982). In terms of educational activities and the educational environment, educational designers need to plan for the occurrence of special cause events (fires, tornados), but they typically have no control over these special cause events. On the other hand, educational designers do have the ability to reduce common cause events and problems associated with such variability.

The task of balancing a broom on the open palm of one's hand, broom bristles up, provides an example of common cause variability. The laws of physics introduce a great deal of variability and can make this task quite difficult. An accomplished balancer has the expertise and skills necessary to balance the broom; however, most people would scurry around trying, with no avail, to keep the broom balanced. Most individuals simply do not possess the skills necessary to overcome the variation inherent to the process to successfully perform this job.

However, if the process is redefined by holding the broom in two hands, and introducing some technology, such as bracing the broom handle against a desktop, many more people can successfully perform the task. The redefined process and use of *enabling technology*, technology that enables improved performance, makes the task more accessible by reducing the variation inherent to the process. This illustrates a typical strategy for reducing the variability associated with processes: redefine the processes and incorporate enabling technology.

Workplace organization, standardized work procedures, and the use of visual controls all help reduce common cause variability. For example, the parking place lines and directional arrows present in parking structures organize the parking environment. As long as people understand and comply with these visual controls, the environment is largely self-managing. The knowledge built into the environment helps everyone perform correctly and allows optimal utilization of parking resources. The self-managing features of workplace organization, standardization, and visual controls built into the environment reduce the variability of human performance and create more stable, predictable environments for everyone (Erlandson, Noblet, & Phelps, 1998; Erlandson, 2001b; Erlandson et al., 1997).

Likewise, educational designers need to utilize design principles that reduce the common cause variability inherent in educational environments. Providing a safe, clean, and comfortable facility is an obvious and critical step. Creating a classroom flow that minimizes movement around the room and hence the opportunity for students to bump into each other and cause disciplinary problems is another technique for variation reduction. Providing environments that are more self-managing is another step. Figure 6 shows a shadow diagram in a shop. This simple technology provides significant self-managing features as well as error-proofing. Everyone knows by looking at the board if a tool is present. Everyone knows to put the tools back over the corresponding shadow diagram.

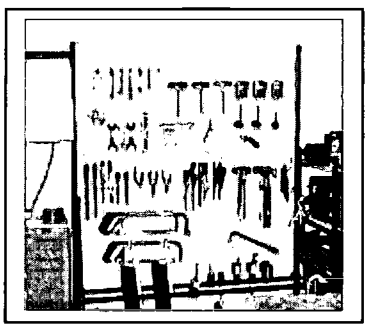

Figure 6. A shadow board builds knowledge into the environment and creates a more self-managing environment.

Conclusions

The UDL principles of equitability, ergonomic soundness, perceptibility, cognitive soundness, error management, flexibility, and stability/predictability work synergistically. For example, Figure 7 shows three sets of dials. If the educational objective is to conduct an experiment wherein the dials (representing some part of the experimental setup) must be in the proper range for the experiment to proceed, then reading the dials is a non-value added activity not the essential learning objective. UDL principles would suggest use of the Level 4 arrangement. The experimenter can quickly see if the dial readings are appropriate. Not only are they within the marked area, but they are all vertical. This is a quick pattern recognizing cognitive operation, one that people are very good at. The Level 1 arrangement requires interpreting the three dial positions, a highly error prone operation with a large amount of inherent variability. The Level 3 arrangement is less error prone and possesses less inherent variability but still requires more cognitive effort than Level 4. In this example the visual controls build knowledge into the environment; thereby facilitating a more self-managing environment. Since the visual controls work for everyone, they are non-stigmatizing as they provide error proofing.

The systematic application of UDL principles creates educational environments that support competent participation by all students. UDL principles are good design principles that support a variety of learning theories. Educational designers can use the UDL principles to create more efficient and effective educational environments, curricula, materials, and activities (Erlandson, 2001a; Erlandson, 2001b).

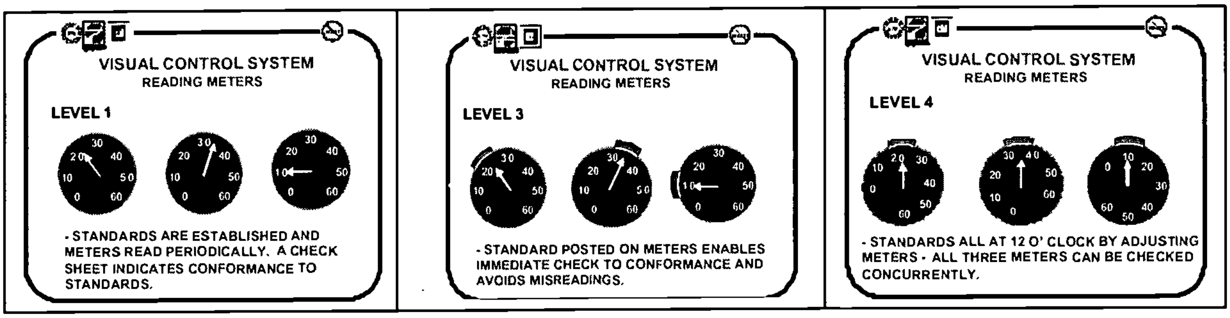

Figure 7. An example of error-proofing using visual control, drawn from the General Motors Quality Network Workshop series on the application of quality and process improvement tools.

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