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Elemental and Synthetic e-Learning

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***Abstract*— This paper presents an integrated framework that emphasizes elemental learning. The model, based on learning analysis and direct measurement of learning is iterative, as opposed to a front-end-only approach, and includes five major cognitive learning outcomes: actual elements, simulated elements, procedural understanding, conceptual understanding, and related knowledge.**

***Index Terms*— e-Learning, learning outcomes, Pedagogical models, Course design**

I. INTRODUCTION

The *integrated framework* in this paper consists of a hierarchy of elemental and synthetic e-learning outcomes. It is less formal than a specialized educational taxonomy but potentially useful for conducting a naturally occurring iterative process of learning analysis. Although the framework is intentionally less specific than a learning taxonomy, it lies somewhere along the situated side of the transfer continuum largely because of its emphasis on the elemental learning outcomes described below.

II. LEARNING OUTCOMES AND FIDELITY

Learning taxonomies such as the classics of Bloom [1] and Gagné [2] are important because they give us a structure for learning analysis, i.e., figuring out the rational intended learning outcomes in a particular situation or for a particular learning process. There are many other versions of learning taxonomies useful in specific situations for analyzing learning outcomes. We might want to conduct learning analysis for assessment purposes or to plan or just understand learning. Because learning outcomes are essentially a way to analyze content, it really does not matter how an individual acquires content or, in the case of intentional learning, how the content is taught. Additionally, taxonomies are important to identify the nature of incidental, or unintended, learning outcomes. Likewise, taxonomies can be very useful in the assessment of learning outcomes.

So, if classifying learning outcomes by using learning taxonomies helps, why don't we use taxonomies more often? Simply put, they are awkward and sometimes even misleading. Sophisticated approaches to analyzing learning outcomes are very useful for artificial intelligence learning applications, adaptive computer-based testing, and expert systems-type wizards. Yet, there are limited adoptions by most e-learning educators. Learning analysis, if it takes place at all, is more likely to be a process of intuition or trial and error.

A. Rethinking Learning Analysis

Analysis and design of meaningful learning and assessment can be considered both elemental and synthetic. Elemental learning outcomes are the constituent components of learning. These refer to the actual, real tasks in an actual or close proximate environment in which the learning outcomes will be used. Elemental learning outcomes are context- and content-specific but may also contribute greatly to learning similar elemental outcomes by virtue of the learner's enhanced experiential schema. They are situational. They are real or as "almost real" as possible. They are, for example, navigating a ship's course on the ship or via a simulation. They go beyond, but are dependent on, the synthetic foundations of knowledge, skills, or attitudes. In contrast, synthetic learning outcomes are the cognitive learning outcomes necessary to support elemental learning. Synthetic here refers to forming something new (supportive or critical to elemental learning) by combining other, usually decontextualized, outcomes. These are the traditional learning outcomes. In taxonomies such as Bloom's or Gagné's, these are normally believed to be hierarchical. For example, learning rules always entails prior learning of certain concepts; some basic knowledge is involved, and so forth. Synthetic learning outcomes are less context-specific, and the learner's experience is often less important in acquiring these outcomes.

Consequently, one approach to learning analysis and design would be to embody analysis only on elemental (real-life or simulating real-life) outcomes and, when these are identified, look for those synthetic outcomes that support this as meaningful learning [3]. Learning strategies that support these outcomes in e-learning or virtual worlds might include some type of apprenticeship with a person or an avatar. A simulation could include an embodied experience such as suggested by Gee's [4] Situated Meaning Principle. This conceptualization can lead us to a simpler, more direct framework useful for assessment and the design of intentional and unintentional learning

B. Fidelity of Design: Elemental and Synthetic Learning Outcomes

Fidelity of learning design is *the* quality indicator of learning analysis *and* learning assessment. For example, the ultimate goal of an e-learning simulation may be to produce competent electricians to repair or replace electrical circuits aboard ships. A course or module of that curriculum could be aimed at trainees' ability to apply Ohm's law to DC circuitry. Another module might be aimed at troubleshooting actual electrical failures. In most electrical training approaches, the first module would be assessed (and taught) using abstract formulae or, at best, circuitry diagrams. This is a synthetic learning environment, because by teaching and measuring only the lower-level formulae and diagrams without the troubleshooting component, we decontextualized the real “on-the-job” environment. The “on-the-job” environment requires technicians to incorporate Ohm’s law and knowledge of DC circuitry into troubleshooting real electrical circuits. This is true fidelity to the ultimate transfer task. This is an elemental learning environment. A greater emphasis on learning and assessing learning at the stage of actual elements holds the most promise for real fidelity and transfer of learning, especially in training environments. Analyzing learning should reflect that. If there are voids below elemental learning, their need will become obvious in practice.

In this paper, we depict an instructional design framework that consists of elemental learning (actual and simulated elements) and synthetic learning outcomes (usually decontextualized procedures, concepts, and knowledge). Elemental and synthetic learning outcomes are both essential, but fundamentally distinct. Actual and simulated elements (elemental outcomes) involve assessing or learning the real-life task or a simulation of that task. Synthetic learning outcomes do not.

III. A PYRAMID OF LEARNING FIDELITY

Figure 1 presents a visual metaphor for how elemental and synthetic outcomes are interrelated. The top levels of the pyramid concern elemental outcomes (actual elements and simulated elements). The lower levels are the synthetic learning outcomes (procedural understanding, conceptual understanding, and related knowledge), which concentrate on building traditional cognitive skills. The term “synthetic” is not meant to disparage the importance of creating substantial support for elemental learning using these important foundational levels. They are critical to attain and enrich elemental learning. What is meant is that the point of learning is to perform real-life or actual tasks (actual elements) or, from a learning perspective, practical approximations of reality (simulated elements). e-Learning aimed at elemental learning does not ignore synthetic learning outcomes; rather, it integrates them naturally and iteratively based on need.

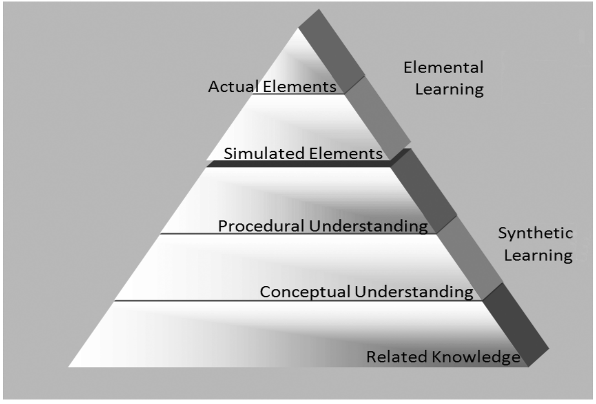

Figure 1. Elemental learning pyramid culminating in actual elements. The top two levels are elemental learning outcomes. The bottom three learning outcomes are viewed as synthetic.

IV. ACTUAL ELEMENTS

The most direct level of learning is the real-life learning outcomes required by the actual environment in which the learner needs to use those learning outcomes. If you are really going to be a respiratory technician, for example, at some point you need to actually work as a technician with real patients and with all of the attendant repercussions for failure. Not all learning needs to be measured at this level, but many real-life tasks do—especially critical skills (e.g., conducting invasive health care procedures under supervision). In some cases, of course, teaching and assessing actual elements may be either too expensive or too dangerous.

A. Actual Elements Design Propositions

1) Actual elements learning outcomes result from the need to learn something in real life.

Educators should ask how the technological affordances in e-learning and virtual worlds can contribute to performing actual tasks. At one end of the need continuum there are very specific tasks such as learning to wire a florescent lamp. The other end of the spectrum includes ill-defined needs such as the ability to negotiate favorable terms in commercial real estate transactions.

2) One way to approach the complexity of learning design is to begin with meaningful assessment.

Meaningful assessment has to do with the process of gathering evidence of student learning outcomes. Actual elements tasks should first and foremost represent true fidelity to the actual or ultimate transfer tasks. At the same time, the actual tasks in certain “real-life” situations may be unclear (e.g., interpreting unfamiliar cultural contexts). So, rather than thinking about designing instruction, we need to remember what we are really trying to do is to make sure that learning takes place. As all of us know, learning is often incidental anyway (i.e., it takes place outside of intentionally designed instructional environments). So, what is our essential task as a designer of instruction? The common sense response to that question is to figure out how we will estimate what learners will be able to do. If we can find an effective way to estimate, or assess, what learning should take place, everything else will fall into place.

3) Designing for actual tasks is almost always an iterative, cyclical process.

Consider a relatively difficult actual task such as being able to present a short extemporaneous speech on an unfamiliar topic. Once you are clear how that could be assessed in real life, iteration, intuition, and experience should guide the learning. Except for very simple tasks, don’t look for an algorithm. Instead fill in those elemental and synthetic learning outcomes that circumstances dictate. As you go through the course development process and get a better handle on the learning and assessment strategies you will use, the genuine goals of the course will be clearer to you. In an artfully designed course, your final course goals will be the subject of some revision. This is the natural and healthy practice of iterative course design. Good design is almost always good revision.

4) It makes sense to practice the actual elements task as much as possible.

There is an old saying that goes something like, “In theory there is no difference between theory and practice, but in practice there is.” Assessing whether someone can *say* something (related knowledge) or *understand* something (conceptual or procedural understanding) is not assessing whether someone can *do* something. If only to create an equitable learning environment, it just makes sense to sufficiently practice actual elements you think should be assessed. Again, employing the assessment of an actual task is not always necessary or even possible in all learning situations.

V. SIMULATED ELEMENTS

An increasing amount of e-learning from virtual worlds, certain role-playing games, or other simulations is assessed at this level. Simulations represent the essential features of something. In many cases, simulated elements promote learning transfer; i.e., they reproduce reality or some version of reality “close enough” to actual elements for even advanced stages of learning (e.g., helicopter simulators).

A. Simulated Elements Design Propositions

1) Effective educational simulations address the variables of curiosity, challenge, fantasy, and control and pay heed to gender, nationality, and culture.

A seminal work by Malone [5] called attention to the importance of including three factors into games including simulation games: challenge, curiosity, and fantasy. Later research has detailed the marked differences in the types of scenarios and games preferred by males and females [6] and the importance of control in addition to Malone’s three original factors [7].

2) For simulation or sim games with narrative involvement whether reality-based or fantasy-based, the importance of the backstory cannot be overstated [8].

The backstory creates the reason for someone to want to be part of a simulated reality and “hooks” the learner into caring about the scenario. Designers can reveal the backstory by using narrative, recollections, flashbacks, or any number of “widgets” built into the environment that encourage to user to engage with the background story.

3) It is important to provide contextualized advisement or agent input for noncompetitive simulations or simulation games.

Research by Van Eck and Dempsey [9] found that learners in a video scenario-based simulation on practical mathematics skills had a higher transfer rate when advice and comments related to the task were contextualized. Those that were in a competitive condition did best when no contextualized advisement was present.

4) Encouraging some form of emulation or “buy-in” in a simulation helps to promote acquiring or changing attitudes.

Simulated elements are ideal for attitude learning. As discussed above, we often acquire attitudes by emulating a human or a humanlike entity. This entity becomes an “influencer,” situated in our thinking

VI. PROCEDURAL UNDERSTANDING

Procedural understanding can involve fairly simple rule-using processes such as those applied in arithmetic. On the other end of the spectrum, higher-order procedures like those involved in medical specialties can be ill-defined and very complex in their scope. In other words, procedural understanding requires that learners perform tasks rather than merely understand how to perform them. Even though it can be very complex, in and of itself, procedural learning is not an elemental learning outcome because it is missing essential features of the context..

A. Procedural Understanding Design Propositions

1) All procedures, processes, and rules of any sort are composed of multiple concepts (Gagné, 1985).

For example, rules of the arithmetic procedure of division require that learners understand the concept (NOT the verbal definition) of dividend, divisor, quotient, whole number, and so forth. Designers concentrating on procedural understanding games or virtual activities should make sure that essential prerequisite concepts and rules are addressed adequately.

2) Particularly as procedures become more complex, advisement becomes a critical part of the learning process.

One form of advisement involves feedback, but advisement is guidance and tutoring as well. In his classic “2 Sigma” article, Benjamin Bloom [10] “found that the average student under tutoring was about two standard deviations above the average of the control class (the average tutored student was above 98% of the students in the control class).” (p. 4). This was and still is startling, and these studies have been replicated on multiple occasions [11]. These findings essentially indicate that tutoring is the most effective tool we know about to increase achievement and retention. Unfortunately, in many procedural-learning situations, individual tutors are just not practical—particularly for general synthetic learning outcomes. Therefore, the next best thing is to design in some form of advisement that can be solicited by the learner. This runs the gamut from pull-down menu help to intelligent agents. What has not held up well are highly intrusive or unsolicited help “agents.” Does anyone remember Microsoft Bob? http://en.wikipedia.org/wiki/Microsoft_Bob)

3) What Gestalt psychologists first referred to as “insight” is important and should be interactively addressed to promote procedural understanding, or conceptual understanding in the case of complex abstract concepts.

Basically, insight occurs when learners reorganize or restructure their perceptions in order to really “see” the solution. According to Gredler [12], there are three possible mechanisms for restructuring a problem: reencoding, elaboration, and constraint relaxation (p. 55). Reencoding occurs when an incorrect or somewhat inaccurate interpretation of a problem or a procedure is corrected. Elaboration involves retrieval of additional information from long-term memory or adding overlooked information to the problem. Constraint relaxation amounts to removing unnecessary boundaries or limitations that learners impose on themselves (e.g., only doing it the way they’ve always done it).

VII. CONCEPTUAL UNDERSTANDING

The next level of learning involves understanding concepts. These can be both concrete (e.g., automobile) and abstract (e.g., altruism). Conceptual understanding can benefit from but does not usually require verbal knowledge or an intelligible verbal definition. Conceptual understanding can be learned (and assessed) by novel examples and nonexamples, by metaphors, and by deductive observation and reflection. For example, we all know what "faith" is, but the concept is different for each of us.

A. Conceptual Understanding Design Propositions

1) A learning activity or digital game teaching concepts should in some way address three common types of error: misconception, overgeneralization, and undergeneralization.

Misconception means that the learner is simply totally off track. He or she thinks the concept is one thing, when it is clearly another. This often occurs when the concept is new and usually requires examples that epitomize the concept. Overgeneralization or undergeneralization, by contrast, are more nuanced errors that require exposure to examples whose attributes diverge from the epitome, or prime example. In these cases, the examples must be novel or unfamiliar examples that can, with feedback or an Aha! moment of some sort, refine the conceptual understanding.

2) Conceptual understanding can be learned (and assessed) by actively classifying examples and nonexamples with feedback using the computer's dramatic ability to keep track of on-task performance [13],[14].

This singular characteristic of the computer, its ability to capture and use variables inputted by the user, is not employed nearly often enough in correcting obvious conceptual error. Combining the structure of concept learning with a rule-base framing structure is an efficient and moderately thorough method of learning concepts ideally suited for hyperlinked environments [15],[16].

3) Conceptual understanding should be fostered with metaphors. Metaphors play a crucial role in defining our shared understanding, and in turn, our concepts.

As Lakoff and Johnson [17] put it, "Metaphors are fundamentally conceptual in nature…grounded in everyday experience," and "unavoidable, ubiquitous, and mostly unconscious." (p. 272). Clever design benefits from metaphors in which the source domain (the one in which the metaphorical reasoning takes place) provides a utilitarian vehicle to reach the target domain (the subject matter).

4) We educators should promote a process of inductive observation and reflection. In the right environment, learners can work through to conceptual understanding.

In the right place, in the right time, acquiring conceptual understanding can be an elegant and flowing mental process. Concepts are often wide enough to use for a variety of elemental learning outcomes, whether they are new to the learning situation or they have been learned in the past. One thing actual elements do for us, however, is to focus the learner on the *meaning* of concepts as a means to perform a real-life task well.

VIII. RELATED KNOWLEDGE

The base level of the pyramid is the related knowledge of the content area. This includes simple physical discriminations (e.g., matching machine screws), knowing about simple motor skills, labels, facts, and summary information (even complex summaries). Learners can acquire related information incidentally (e.g., from a television program on another subject) and intentionally (e.g., from an Internet resource accessed via a handheld mobile device). Definitions, whether memorized exactly or paraphrased, are examples of related knowledge—not concepts.

A. Related Knowledge Design Propositions

1) An efficient corrective feedback scheme (feedback for wrong responses) should be repeated using an efficient short-term rehearsal scheme.

Computer databases are adept at capturing and repeating knowledge items that were responded to incorrectly. Further, there are a number of relatively straightforward adaptive schemes that have proven effective for algorithmic presentation of drilled items.

2) The level of difficulty should be adjusted based on user response correctness.

The primary purpose for this is to increase challenge, long considered a critical component of motivation and educational games [5].

3) There is no need to repeat related knowledge questions and feedback to content learners have already responded to correctly unless there are reasons to suggest that connections to that content are weak [18].

An exception to this proposition is when a high rate of fluency or automaticity is required by the actual elements task [19].

4) Long-term retention can be aided by connecting the related knowledge to the actual elements task and by scheduled cumulative practice.

Using himself as his only research participant, the seminal empirical work of Hermann Ebbinghaus [20] on forgetting still has a number of implications for learning design. Ebbinghaus showed that it is harder to memorize material that is not meaningful. His experiments also suggested that increasing the amount of verbal information to be learned greatly increases the amount of time needed to acquire it. (This is the famous "learning curve.") Importantly, his data also indicated that we learn more by spacing out the verbal information over time than by trying to learn it in one session.

IX. OTHER LEARNING OUTCOMES?

What about motor skills and affective learning? Aren't they important learning outcomes? Absolutely! We would argue, however, that in most cases these learning outcomes fit comfortably within the actual elements pyramid chiefly because we learn them by doing something elemental—either something real or an approximation of that reality. Otherwise, there would seem to be little point in learning motor skills or attitudes at all.

A. Motor Skills

One way to look at motor skill learning is that we learn them via practicing part skills and honing a calculated executive control process. Part skills are synthetic learning outcomes and often follow a particular procedure (part 1: reach for the mouse; part 2: look at the computer screen and locate the cursor; part 3: press down on the left mouse button; part 4: move the cursor to the desired location on the screen; and so on…). The executive control process that guides motor skill actions is driven by actual or simulated elements (actual tasks or their approximations). We can see that especially by considering the purpose for learning fine motor skills to any degree of control and precision. A foreigner does not learn to eat flawlessly with unfamiliar utensils according to local customs without a goal related to the local culture at the actual elements (real-life) level. It is in simulating or performing the actual task of eating in the foreign culture that the motor skills are acquired.

B. Attitudes

How do we learn our attitudes? How do we "change" an attitude? One way that we know from practical experience is by emulating a human or some human-like entity in an actual or simulated environment (actual elements). As very young children, we emulate our parents or those around us in a kind of mimicry. As we develop emotionally and intellectually, the sphere of "influencers" broadens greatly and will include many people or people-like entities we don't know (movies stars, avatars, sports figures, androids, or theorists).

X. BRUNER AND SPIRAL CURRICULUM: ITERATION, INTUITION, AND STRUCTURE

According to Bruner [21], "A curriculum as it develops should revisit basic ideas repeatedly, building upon them until the student has grasped the full formal apparatus that goes with them" (p. 13).

Bruner focused on environmental and experiential factors and culture. In referring to children, Bruner hypothesized "that any subject can be taught effectively in some intellectually honest form to any child at any stage of development" (p. 33). Intuition is a critical part of this process. Bruner often referred to intuition in relation to experts performing real tasks where they "leap intuitively into a decision or to a solution to a problem" (p. 62).

A focus on elemental learning allows for intuitive leaps as our abilities to function in the world are developed and our ability to perform actual elements tasks increases. Intuitive leaps are related to what has been referred to in medicine and other areas, such as physics, as the forward reasoning (from data to solution) applied by experts versus the backwards (rigidly algorithmic) reasoning of novices.

This intuitive, active, iterative and spiral curriculum approach toward actual elements fits enormously well with rich e-learning environments, which can be intuitive and motivating. This critical "effort" attribute of learning motivation is enhanced by high interactivity and, in many cases, social interaction practical in many e-learning environments.

The elemental learning framework has its foundations in the spiral curriculum. Complex learning outcomes (*converse fluently with the people in a French-speaking country*) can be accessible in basic situations first and revisited in more complex situations later on. This is not repetition. The learner revisits these situations iteratively and each time the learning deepens by building on prior experience. Synthetic learning outcomes are given meaning by being situated as much as possible in the actual or simulated learning outcomes. Another parallel with both the spiral curriculum and the motivational literature is that challenge (difficulty) is increased as the learner's competence increases.

XI. CONCLUSION

The best kind of learning is aimed at achieving or supporting something actual. Actual in this sense is meaningful, purpose-driven, and useful to learners' real lives. Tourists who plan to drive in a new country are anxious to learn to identify unfamiliar road signs (conceptual understanding) because it directly affects their potential ability to safely travel (actual elements). There are also some vocabulary (related knowledge) and regulations (procedural understanding) that supports their travel. These are simple learning outcomes, but if they were more complicated, it would make sense to artificially replicate the actual travel environment (simulated elements) before attempting to drive. In any case, it is elemental learning that motivates us to make the trip in the first place.

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