Integrating Field Research, Problem Solving, and Design with Education for Enhanced Realization

Mohamed El-Sayed
Kettering University
Mechanical Engineering
Flint, MI, 48504 USA

and

Jacqueline El-Sayed
Kettering University
Mechanical Engineering
Flint, MI, 48504 USA

ABSTRACT

Developing the right set of educational objectives and activities are some the key factors for a successful education program. Since almost all educational processes intend to improve quality of life or realty it is important to consider the human interaction with reality and its objectives before designing the educational experience. In this paper the concept of realization or dealing with reality is revisited in an attempt to address why the field activities of research, problem solving and design should be integrated with the educational programs.

The expanded realization concept includes the virtual and perceptual realities as valid domains of realization. These domains of realization and their interactions with the physical reality are studied along with the relationships between research, problem solving, and design. Bloom's cognitive domain educational objectives are also aligned with the expanded realization concept. Finally, to provide a model for how the field activities of research, problem solving and design could be integrated with an education program, and to assess the role of different learning experiences in achieving enhanced realization, an engineering case study utilizing alumni survey data is presented.

Keywords: Realization, Education, Research, Problem Solving, Design, Perceptual, Virtual.

1. INTRODUCTION

There have been a growing number of national reports and articles that document the need for incorporating innovative forms of teaching [1, 2]. To design, reform, or continuously improve an educational program, a set of clear educational objectives must be defined. In addition, all learning experiences, courses, and activities, must be streamlined and aligned to deliver the desired learning outcomes and ultimately achieve the objectives. The program outcomes should always be derived from the program educational objectives and not the reverse. Therefore, developing a meaningful and effective set of educational objectives will always be the cornerstone for success in education. In the following a study for integrating field activities of research, problem solving and design with the objectives and activities of educational programs is conducted. In addition, to demonstrate and assess the results of such integration an engineering case study is discussed.

2. REALIZATION AND REALITY DOMAINS

For understanding the role of research, problem solving, design, and education in enhancing realization it is important to specify what the term realization actually means. A definition, that reflects the current use of word realization, considers realization as [3]:

1. An act of figuring out or becoming aware.
2. The act of making real.
3. The result of an artistic effort.

Building on this definition it can be stated that the act of realizing is the interaction with a reality to figure it out, utilize it to achieve desired results, and alter it by eliminating or bringing new objects to it. Therefore, realization is the interaction with a reality to:

1. Understand it
2. Utilize it
3. Alter it

It is also clear from the current definition that reality could be expanded to include other dimensions or domains that go beyond what is physical. Among these dimensions the following three forms or domains of reality are considered [4]:

1. *Physical reality*: represented by the physical universe we live in and can be realized with our senses such as seeing, hearing, touching, smelling, and tasting.
2. *Perceptual reality*: represented by our individual paradigms or the internal image of other realities.
3. Virtual reality: represented by the virtual modeling and simulation of physical, perceptual, and other realities.

By examining all three realities, it could be observed that the perceptual is the domain where the individual realization is being formulated (developed and validated). While perceptual reality is unique and may be subjective, for each individual perception is reality. For example, the act of having a new perception or paradigm shift is an act of realization. An individual will usually use the phrase "I realized" when a new perception or a perceptual paradigm shift happens.

The virtual domain is the domain where collective and shared perceptions are being formulated (developed and validated). For example, when some information or knowledge is shared a new shared perception or a virtual realization is created.

The physical domain is the domain where physical reality is being actualized (developed and validated). For example, when perceptual realizations of a design team are shared in the virtual domain and manufactured an altered reality is achieved in the physical domain.

In all three domains of reality there are interacting elements or objects specified by:

- Forms (shapes and substances)
- Functions (purpose and performance)
- Interactions (actions and reaction) with other object through fields of activities (interaction fields).

The transfer between the three reality domains is through mapping. The main two elements for mapping are modeling and simulation [4].

A model: is a representation of an object. Depending on the reality domain a model is:

- A physical representation of an object (physical)
- A cognitive representation of an object (perceptual)
- An abstraction using mathematical language or computer programming to represent an object (virtual)

A simulation: is the act of an object or its model performing in an actual or simulated environment. Simulation is used to show the actual or eventual performance of an object in the actual or intended environment. Simulations are used in all three reality domains:

- Physical simulation or actual utilization of an object actual or physical model (physical domain)
- Mental simulation of an object's perceptual model (perceptual domain)
- Virtual simulation of an object virtual model (virtual domain)

Key issues to consider in mapping through modeling and simulation between domains are:

- Acquisition of valid information about the object for accurate representation of the object and its environment.
- Selection of key characteristics and behaviors to establish meaningful correlations.
- Use of simplifying approximations and assumptions
- Fidelity and validity of the modeling and simulation.

To map objects and their environment between different realities using modeling and simulation requires deconstructing and reconstructing using analysis (for deconstructing) and Integration (for reconstructing).

To illustrate the realization concept discussed so far consider the following example [4]: An object represented by a football in the physical domain, made of a specific form and materials, interacted upon by a quarterback who is throwing it to a receiver in a football field during a game. At the time of the throw the wind in specific direction is 15 mile per hour. The quarterback perceives the whole physical domain of the field in his perceptual domain through the perceptual modeling ability (interaction between physical and perceptual domains). Before throwing the ball he performs a perceptual simulation of the location of the receiver, the speed, and direction required to place the ball at the hand of the receiver away from the defenders. The receiver models and simulates the physical reality in his perceptual domain and translates it into a physical movement to be at the right place and right time for making the catch (interaction between physical to perceptual and perceptual to physical). For the viewers watching the game being broadcast on T.V. the physical reality on the field is communicated (mapped) through the virtual reality to the perceptual reality of the viewers (interaction from physical to virtual and from virtual to perceptual). It can be noticed that for the viewers each perceptual realization to the physical reality on the field may be slightly different from the others due to the emotional, cognitive, objectivity, and experience level with the game. Moreover, while reading this virtual example written in the physical domain, the reader has formulated a perceptual domain image of the situation (interaction between perceptual and virtual domains).

Both analysis and integration use modeling and simulation at different degrees [4]. As shown in Fig. 1, analysis is performed with mostly simulation and some modeling while integration is performed with mostly modeling and some simulation. It is also obvious that both analysis and simulation are logical and analytical in nature while modeling and integration are more holistic and creative in nature.

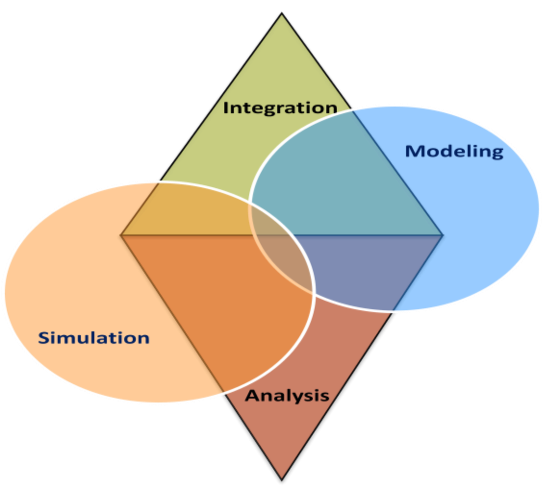

Figure 1 – Different realization processes

3. REALIZATION ACTIVITIES

The main objectives for interacting with any reality are:

1. To understand it (know it)
2. To utilize it (use it)
3. To improve it (alter it)

These three objectives are interconnected and overlapping because utilizing or altering a reality requires an understanding of it. Also utilizing or altering a reality brings a better understanding of it. In addition, these three objectives create the following three distinct but interconnected human and reality interaction activities:

1. *Research:* aiming at understand reality
2. *Problem solving;* aiming at utilize reality
3. *Design*: aiming at improving or altering reality

These activities can happen in any reality or across all three realities. Also, the aim of each activity does not exclude the activity from achieving other objectives. In other words, to understand a specific reality may require the utilization of another reality and improve a third reality. For example, performing research to understand a specific phenomenon in the physical domain may require the use of the virtual domain to improve the unacceptable state of lack of understanding in the perceptual domain. Each of the three activities is started due to one of the following states and ends after reaching another state of the three, as shown in Fig. 2. These states are [4]:

1. *Unacceptable Reality*
2. *Acceptable Reality*
3. *Improved or altered Reality*

Figure 2 – Beginning and end states for different activities

As shown in Fig. 2, research starts due to unsatisfying state of understanding in the perceptual and virtual domains and ends by reaching a state of improved understanding at the perceptual and virtual domains. Problem solving starts due to unacceptable state (things are not the way they should be) at any of the three domains and ends by reaching the desired state (things are the way they should be) at same domain. Design starts from a state of acceptable reality due to the desire for improved reality in the physical or virtual domains and ends by reaching a state of improved or altered reality at the physical or virtual domains. It is important to recognize that while the starting domain can be different, for each activity, all three activities are initiated by the perceptual domain. Each of three activities can be further explained as:

Research

Research is an activity initiated and conducted by the perceptual domain aiming at understanding all three reality domains. While a research activity may utilize the virtual or physical domains the goal state is always an improved state at the perceptual domain.

The processes to perform research are mainly analysis and integration. Analysis is mostly conducted utilizing the perceptual domain and performed in the physical domain with the help of the virtual domain as needed. The gained insights are usually integrated utilizing the perceptual domain and communicated through the virtual domain. Both analysis and integration use modeling and simulation across the three domains as sub-processes at different degrees. For example, to improve the efficiency of a specific product the need for conducting research was created. This research would start due to unacceptable state of understanding for the product performance and the parameters affecting it. The research would be conducted until a desired improved state of understanding is reached, before attempting to change the current design. Utilizing the perceptual domain of the researcher(s) and conducting the research in the physical and /or virtual domains, through testing physically simulated models and /or virtually simulated models of the product, could produce an improved state of realization in the researcher(s) perceptual domain. If the research results are documented and communicated or published an improved state of realization in virtual domain would result as well.

Problem solving

Problem solving is an activity initiated and conducted by the perceptual domain aiming at transforming unacceptable state of reality to acceptable state of reality in all three domains. Problem solving activity may take place in the perceptual, virtual, or physical domain the goal state is always an acceptable state at the domain of the starting state.

Similar to research, the processes to perform problem solving are mainly analysis and integration. Analysis is mostly conducted utilizing the perceptual domain and executed in the physical or virtual domains depending on the problem context. In educational settings solutions are usually performed in the virtual domains. The gained insights are usually integrated utilizing the perceptual domain and used to solve the problem in the execution domain. Both analysis and integration use modeling and simulation across the three domains as sub-processes at different degrees until the acceptable state of the problem solution is reached. For example, if during a research activity an object is not working as expected in any of the three domains a problem is identified by the perceptual domain. To develop a solution may require the utilization of the virtual or physical domains in addition to the perceptual domain until a solution is reached in the same domain where it was identified.

Design

Design is an activity initiated and conducted by the perceptual domain aiming at altering reality from an acceptable state of reality to improved state of reality in the physical and/or the virtual domain. While design activity may take place in the perceptual, virtual, and physical domains the goal state is always an improved state at the domain of the starting state.

The processes to perform design are mainly integration and analysis. Integration is mostly conducted utilizing the perceptual domain and executed in the physical or virtual domains depending on the desired end product context. In educational settings designs are usually performed in the virtual domains. The problems or lack of understanding faced during integration are addressed through problem solving and research performed using analysis and integration. Perceptual domain creativity is usually utilized to solve the design integration issues in the execution domain. Both integration and supporting analysis use modeling and simulation across the three domains as sub-processes at different degrees until an improved state of reality with a new product design is reached. For example, utilizing the improved perception during a research activity to design a new product can produce an improved performance in the physical domain.

It must be noted that while the initial state trigger a specific activity the other two activities may be involved to achieve the end state. For example it may take some research and design activities to solve a specific problem. In fact some design engineers and researchers due to their analytically dominated thinking and training in problem solving like to start their design (a creative activity) by defining what they call the design problem [4].

4. REALIZATION AND EDUCATION

Understanding the reality domains and realization activities is important for the design and development of a highly effective education programs. In addition, since all realizations are propelled and conducted by the perceptual domain it is important to focus on how perceptions are formulated (physical and virtual realities mapped or modeled and simulated). Both teaching and learning are perceptual domain exchanges between the teachers and the learners. These exchanges are usually shaped by the educational objectives in addition to the teachers and the learners thinking preferences. Bloom's classified educational objectives into the following three domains with different levels of objectives in each [5]:

- Cognitive (thinking skills)
- Affective (values and emotions)
- Psychomotor (movement skills)

Focusing on the objectives related to the perceptual domain activities of problem solving, design and research the following are Bloom's cognitive domain objectives:

1. **Knowledge** – information gathering without necessarily understanding, using, or altering it.
2. **Comprehension** - understanding the gathered information without necessarily relating it to anything else.
3. **Application** - using general concept gained through comprehension to solve a problem.
4. **Analysis** – disassembling something down into its fundamental elements.
5. **Synthesis** - creating something new by integrating different elements.
6. **Evaluation** - differentiating the subtle differences in objects or methods.

Aligning these cognitive domain educational objectives with the three main realization objectives discussed previously it is clear that:

1. Knowledge and Comprehension can be aligned with **understanding realty**
2. Application and Analysis can be aligned with **utilizing realty**
3. Synthesis and Evaluation can be aligned with **altering realty**

In other words, Bloom's cognitive domain educational objectives are aimed at developing the knowledge and skills of dealing with a specific reality of a certain field. These objectives are also aligned naturally with the progression to a higher or enhanced level of realization starting with understanding and ending with altering of reality as shown in Fig. 3. In fact Bloom's highest objective of evaluation can only be reached with refined realization at the perceptual domain. Therefore for achieving enhanced levels of realization, educational programs should include conducting research, problem solving, and synthesis activity in the field of the intended reality.

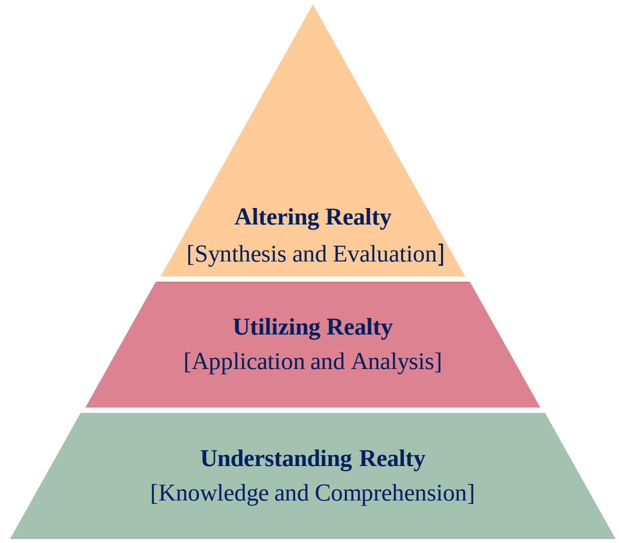

Figure 3 – Progression of Realization Objectives

5. ENGINEERING EDUCATION CASE STUDY

To identify the practices in the field of the intended reality for engineers, the Transferable Integrated Design Engineering Education (TIDEE) consortium of colleges in the Pacific Northwest developed an engineer profile by compiling accreditation criteria, codes of ethics, attributes valued by employers, and core competencies valued by professional societies. Synthesis of these traits produced a set of ten holistic behaviors of an engineer. These ten roles include those of analyst, problem solver, designer, researcher, communicator, collaborator, leader, self-grower, achiever, and practitioner. The Holistic Behaviors associated with the roles and observable actions of an expert engineer are listed in [6]. In this engineering case study the intended field of practice learning experiences, including the TIDEE ten roles, were considered as program educational objectives. In addition to providing the fundamental knowledge and skills needed for professional practices in classroom activities, the program includes a cooperative education experience for each undergraduate student to achieve a targeted level of performance before graduation. In the cooperative education program, the undergraduate alternates between working in an industrial setting and classroom instruction at the university. Through cooperative education, students are exposed to the field reality that they will face as engineers. Students begin their cooperative education rotation normally in their freshman year and must successfully complete multiple cooperative education terms as a graduation requirement. For continuous improvement purposes, the alumni of the program are periodically surveyed about both their classroom and the cooperative education worksite learning experiences. The alumni surveys are usually conducted by the Office of Institutional Effectiveness and adhere to the standard practice in higher education. Surveys are conducted for alumni three years after graduation. The typical number of graduates surveyed is approximately 400 per class with a return rate of approximately 16% [6].

In this case study, the 2008 alumni survey data [6], is used for assessing the role of both classroom and cooperative education learning experiences, in achieving large increase in ability, focusing on the roles of problem solver, designer, and researcher. In addition three other roles of an analyst, practitioner and achiever were added for their significance to this case study. The results are shown in Fig 4.

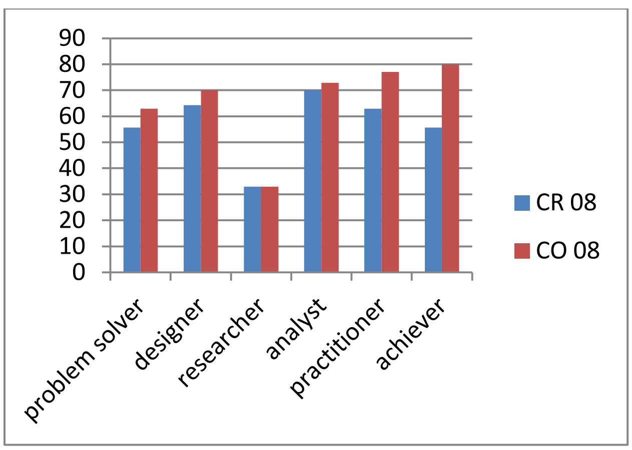

Figure 4 – Setting accounted for a large increase in ability

As shown from Figure 4 the cooperative education real life experience provided higher increase in ability than classroom experience for both problem solving, and design with equal ability in research. Similar increase in ability is shown in analysis which a common sub-process in all other three activities. As it would be expected the largest increases are achieved in the abilities of being a practitioner and achiever.

6. CONCLUSIONS

Since the start of human life on earth two realities have emerged, the physical reality and the human perception of it. To deal with the physical reality and share the formulated perceptions humans introduced the third domain known as the virtual reality. Considering these added realities, the concept of realization could be expanded to include all three reality domains. Therefore, the three types of realization are the perceptual realization which is unique for each individual, the virtual realization which is shared with different individuals and the physical realization which is universal.

Research, problem solving, and design are realization activities performed in different domains. All three activities utilize analysis and integration through modeling and simulation as basic elements of mapping between realities. Therefore, integrating these activities in real life settings is necessary for achieving enhanced realization in any education program. This integration should be started with the educational objectives and implemented with all program and classroom activities.

The presented engineering program case study demonstrates that real life experience has equal or superior effect on enhancing the abilities for conducting all realization activities. However the largest increases in abilities are in the perceptual domains of the learners when dealing with professional realities with the confidence of being achievers.

7. REFERENCES

[1] Baer, J., Cook, A., and Baldi, S., 2006, *The Literacy of America's College Students* (Washington, D.C.: The National Survey of America's College Students, American Institutes for Research.

[2] U.S. Department of Education, 2006, *A Test of Leadership: Charting the Future of U.S. Higher Education*, Washington, D.C.

[3] Wiktionary, 2011. The lexical companion to the open-content encyclopedia, Wikipedia.

[4] *M. El-Sayed, and J. El-Sayed*, 2011, "A Product Realization Approach to Creativity in Engineering Education", ASME Paper No., IMECE2011- 64501, *Proceedings of the ASME 2011 International Mechanical Engineering Congress*, Denver, Co.

[5] Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., and Krathwohl, D. R., 1956, *Taxonomy of educational objectives: the classification of educational goals; Handbook I: Cognitive Domain* New York, Longmans, Green.

[6] J. El-Sayed, M. El-Sayed, S. Beyerlein¸ 2010, "Validation of Hybrid Program Design through Stakeholder Surveys" *International journal of Process Education*, Vol. 2, pp 3-10.