A Computerized Engineering Assessment Method Based on 3D Interactive Multimedia, that Students Enjoy

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Abstract

In this paper we introduce the principles of our novel 3D interactive web multimedia-based educational and assessment methods and solutions, and by focusing on the continuous professional development learners, explain and demonstrate (during our live presentation) a series of case-based learning and assessment modules and eBooks, that encourage reusable 2D and 3D interactive multimedia development, team-oriented learning and problem-solving with real-world challenges.

Our efforts are supported by over 30 academic and industrial partners, assuring the diversity, the relevance and the quality of this rapidly growing library and teaching/learning method. In order to fulfill continuing educational requirements, we have created an object/component-oriented methodology and architecture, that is analytical, quantitative, and open-source computational. Then we have implemented over thirty open source, 3D browser readable, interactive multimedia, web-enabled library cases, covering a wide range of R&D and practical, hi-tech industrial topics.

Introduction

In our advanced learning environment Case-based/Problem-based Learning (PBL) is performed using web-enabled, 3D Virtual Reality interactive multimedia with optional online tutor support in an asynchronous fashion. This allows instruction to be de-coupled from a fixed schedule live classroom, enabling enjoyable interaction, feedback and assessment of learning and problem-solving literally anywhere, anytime. Problem-based learning is by its nature very interdisciplinary.

This learning methodology simulates, and at times replicates, real-world situations and environments. The core of problem-based learning consists of the following fundamentals ([1], [2], [3] and [4]):
Understanding is based on
  - experiences with content,
  - context, the
  - learner’s goals, the
  - educator’s efforts, the
  - live and/or DL institution’s infrastructure support, the
  - individual’s interest and motivation, the
  - society’s pressure and support on all of us to do better all the time, and these
    factors are inextricably woven together. Thus, understanding is a construction
    that is unique to the individual living in a particular culture, including all stresses
    and service in the given culture.

Puzzlement is one of the factors that motivates learning, and in our cases we have included
several interactive exercises to increase this kind of excitement and to encourage learning.

Social negotiation and the ongoing testing of the viability of existing concepts in the face
of personal (and group, peer, and team) experience are the principle forces involved in the
filtering, absorption, reasoning and then the evolution of knowledge ([5], [6], [7], and
[8]).

In engineering, management, biomedical engineering and information technology, the
application of these learning methodologies bring students into situations that combine
laboratory experience with real-world business environments, creating integrated and
complex systems in which specific problems must be solved. Although this
interdisciplinary, open-ended nature makes PBL interesting and engaging, it also poses
challenges to instructors and students that differ significantly from standard classroom
learning ([1], and [12]).

The eTransition process lead by industry in this decade leads towards waste reduction,
innovation and prosperity at all levels, including not just machines, and traditional
engineering processes and resources, but biomedical engineering, medical sciences and
human resources too, since the integrated, collaborative opportunities of product and
process design, information technology and management, must be performed by a highly
skilled, collaborating and continuously learning, dynamic workforce. As part of a traceable
total quality approach (ISO 9001:2000) this needs a sound methodology and a firm
architecture for a continuing education teaching / learning and assessment environment, as
well as for documenting, distributing and managing knowledge, the critical resource of any
company and college / university with a future.

In order to fulfill this need, we have created an object / component-oriented methodology
and architecture, that is analytical, quantitative, and open-source computational. Then we
have implemented over thirty open source, 3D browser readable, interactive multimedia,
web-enabled library cases, covering a wide range of R&D and practical, hi-tech industrial
topics.
Each case in this library first looks at the real-world customer requirement, then experts offer one or more solution(s) by explaining real-world solutions, working with real machines, or processes, or systems, and/or engineering management tasks, and then discuss further development, service, maintenance, integration, connectivity and many other issues with several feedback loops, sound methods, and practical examples. During the discussion, as well as at the end each 3D multimedia eBook case in the library offers plenty of discussion and improvement opportunities, as well as open-source computational solutions and templates for real or virtual teams to test and validate their own logic, and data.

Our approach mirrors real-world issues of the eTransition process lead by industry, as closely as possible in an open source, networked virtual classroom, i.e. on the students' laptop monitors by using various techniques, most importantly the Virtual Product Demo with 3D objects that the students can explore, disassemble and then re-assemble in a matter of seconds, 3DVR interactive objects and 360 degree panoramic virtual tours, and high quality accurate videos containing interviews with product/process experts and time and motion accurate machine / process / system demonstrations ([13] to [16]).

In terms of assessment, our methods never put any stress on students. Because the entire approach is open-source, all parties have access to the same resources and learning tools. Furthermore, our method is analytical and computational, therefore complex issues are explained as well as assessed in interactive 3D, with browser-based, or spreadsheet-programmed easy-to-use software tools that help the learners to acquire, as well as test their knowledge, and find answers quickly, as and when they feel ready to do so.

The benefits of introducing problems for students to solve using cases in a browser-readable 3DVR (three dimensional virtual reality) interactive multimedia format are manifold. The entire learning process becomes more student- versus lecture- or tutor-centered. Students can learn by exploring versus being told, and can have as many goes at solving a problem, or exploring an idea, taking as much time as desired or is available. In ‘our world’ mistakes made can be corrected without penalties. Multimedia tools, or a subset of such technology and a variety of media, as well as traditional methods, such as email access, and telephone links to tutors and other students are available during the learning process.

The Methodology and Examples of Enjoyable Assessment Cases in Our Library

In our PBL library we follow an object-oriented design, therefore our architecture includes case-based library programs that are self-contained, reusable objects built of components. Often these objects and components are text, high quality digital video, animation, 3DVR and animated 360 degree panoramas. They are open source, web-enabled, delivered on the web, or in some cases in CD-ROM or DVD (to overcome transfer rate and in some countries expensive web-access bottlenecks) or fast company intranets for continuous professional development purposes ([6], [11], [13], and [17]).
The ways we present challenges are very similar to the way professional engineers solve problems. This is because we first look at the real-world customer requirement, then we offer one or more solutions by explaining real-world machines, or processes, or systems, or management tasks and then we discuss further development, service, maintenance, integration, connectivity and many other issues. Notice that we do NOT follow the traditional linear, but rather the modern concurrent, object oriented approach to integrated product / process design ([7] and [9]). (In other words, this means, that we design educational projects in a very similar way, hi-tech industry designs hi-tech products and processes.)

In terms of delivering our cases we follow the Virtual Product Demo concept, in that we virtually take the learner with us to factories, R&D studios, exhibitions and laboratories and give them interesting demos explained by real-world experts with challenging problems to solve. In all cases we show them high quality, interactive videos and often 3D objects and 3D 360 degree panoramas of facilities so that they can interrogate them and even participate in digital, virtual 3D factory tours ([8] and [11], and [12] to [14]).

In terms of challenging to learn and investigate the illustrated case further we give several direct URL (web) contacts, e-mail addresses so that the learner can get in touch with key contacts and start to collaborate. We focus our questions and address exciting engineering, management, and computing science / IT (Information Technology) issues. This approach helps distance learners as well as educators to work with the material in real-world classroom and/or virtually web-networked teams.

Our cases are object-oriented and self-contained; nevertheless, they can be integrated or grouped into different classes of objects in a lean and flexible way, just as a modern software program, or a modern manufacturing /assembly system can be integrated into different environments. This enables learners as well as instructors and managers to 'plug-and-play' our cases in ways they choose rather than the way the author meant it.

The methodology we follow enables basic knowledge transfer enabled with 3DVR (3 Dimensional Virtual Reality) interactive multimedia, embedded into a standard browser.

It is highly interactive, collaborative and enables large groups as well as individuals to gain the same knowledge effectively (Figure 1).

Although this method is not for everybody because the problems as well as the solutions are interdisciplinary, often open-ended and can get complex, in all cases our solution will enhance, support and enable a wide range of interactions with real-world challenges ([1], [19] and [20]).

Figure 1 is a typical screen segment of our interactive 3D multimedia screens in the Case Based Learning Library. The left hand side of the screen is usually hyper-linked text and small icons prompting student actions, with the fundamental text content. In the right hand
side of the screen, we offer active code, animation clips, interactive videos in 2D and 3D, 3D objects, 360 degree panoramas and virtual facility tours, and others, that enhance the learning process, and together with the text, images and other media re-enforce the subject area.

According to our experiences, such multi-faceted computing support in education offers a well-rounded experience, that is significantly more enjoyable to learn, than using traditional methods.

![Figure 1](image)

**Figure 1** illustrates one of our typical screens with assessment questions. As can be seen, we explain the topic with some text, videos, animations, as well as 3D interactive objects, that the user can interrogate, and then, as one of our approaches, we ask questions about the learned topic, module-by-module. (Please note, that our original screens are in high quality, full screen and full color graphics, that we had to reduce in size and quality to fit the format requirements of this paper. Please visit [http://www.cimwareukandusa.com](http://www.cimwareukandusa.com), and then click on the Case Library icon to view these screen-prints in high quality).

Individual learner, team learner, group and class assessment is integrated into every module of our programs (supported by active code spreadsheets, often with embedded 3D...
objects, video-clips and animations) that the students can interrogate to understand either the question(s) or the answers better.

Furthermore, in our assessment programs graphs are shown illustrating individual vs. group / class benchmark assessment results. This is very useful, in particular for distance learning students, because they feel that they are equal members of the class. (Traditional, as well as e-mail, web-collaborative, telephone and personal-appointment-based tutorial support is available if required, [14] to [18].)

The entire education process is more suited to satisfy individual needs. Since failure is not exposed in Open Learning situations, fear is not part of the learning and testing process. Students teach themselves, work on their own and the educator's role changes towards a facilitator, consultant and guide, rather than the sole information provider as in the past.

Education does not become boring, because the routine part of the material is taught by the students themselves, by means of the interactive 3DVR multimedia technology, and because the exciting or difficult parts can be reinforced by the instructor. The entire education process is more suited to satisfy individual needs from 'batch size 1 to many' at the same high quality.

To illustrate some aspects of our interactive, 3D browser readable eLearning and assessment architecture, in Figure 2, we present a typical screen segment of a case, in which we introduce our spreadsheet-based tools for post-test purposes.

The questions here can be phrased with multiple-choice answers in mind. The program not only assesses the answers, but also offers revision support with reasoning, in case needed (please refer to Figure 3, as an example).

Figure 2 (below) illustrates further screen segments that enable students to actively manipulate real-world virtual 3D objects, and explore them according to their own interest both during learning, as well as during assessment. (Note, that according to our experience, this approach keeps the students interested in the subject they learn, because they can actively interact with the computer, showing them exciting 3D interactive animations, 2D interactive videos, and active code they can run with their own data; all under their, versus the tutor’s control.)

An other novel aspect of our assessment approach is that it shows a graphical chart, that compares the individual’s results to that of a control group’s statistically averaged results. This puts a distance learner, or an individual learner taking a self-test remotely (e.g. in a dorm room) into a virtual team, by offering the comfort, or the dissatisfaction, in relationship to how his / her virtual classmates are / were doing during the same (or similar) test.
Figure 2 (above) illustrates further screen segments that enable students to actively manipulate real-world virtual 3D objects, and explore them according to their own interest both during learning, as well as assessment, as part of a spreadsheet-based automated assessment program. (Please note, that our original screens are in high quality, full screen and full color graphics that we had to reduce in size and quality to fit the format requirements of this paper. Please visit http://www.cimwareukandusa.com, and then click on the Case Library icon to view these screen-prints in high quality).

**Revision Strategy**

Since your answer for this question was incorrect, we strongly recommend you to do the following:

1. Look up the specific section where the topic area is covered, and then (use the 'Back' key in your browser to get back to this page)
2. Revise the entire chapter again, in more depth.

**Have fun!** Keep in mind that our open source self-learning and assessment method is designed for YOU to learn as much as you can in a relaxed and enjoyable environment.
Figure 3 (above) illustrates an interactive screen-segment, where revision reasoning is performed, and from where the student can decide his/her own revision strategy by clicking on the appropriate hyper-links. (Please note, that our original screens are in high quality, full screen and full color graphics that we had to reduce in size and quality to fit the format requirements of this paper. Please visit http://www.cimwareukandusa.com, and then click on the Case Library icon to view these screen-prints in high quality).

External Impact

At the time of writing, the library contains over thirty industry and academia sponsored modules, covering a wide range of topics, including rapid prototyping, computer networking and the Internet, computer aided manufacturing, requirements analysis and process failure risk analysis in several volumes, automotive telematics and the digital car, quality control and total quality management, concurrent engineering, flexible, lean manufacturing, service robotics, biomedical engineering and 3D low back pain analysis, factory business process re-engineering, and many others.

As one example, the developed and validated computer networking case-based curriculum used NJIT’s new wireless Internet networking laboratory, partially sponsored by the NJ I-TOWER R&D project and our state-of-the-art web-based methodology for multi-media course development. This means, that besides traditional teaching and learning methods, and laboratory activities the first time in NJIT’s history of education, students were using browser readable 3D interactive eBooks, including text, 2D and 3D objects, animation, videos, 3D objects of real components, virtual 3D disassembly methods of objects, active code, network simulation examples, and simulated (virtual) 2D and 3D factory tours that students and faculty could explore and study together.

Furthermore, using old PCs, we set up a simple disassembly line in the classroom, and with the aid of wireless, Internet-linked laptops, students were able to communicate with each other, as if we were networked cells in a real, digital factory ([1], [3] and [5], and [16] to [20]). (For a detailed example of this curriculum, please visit: http://www.cimwareukandusa.com/All_IT420. For further examples, covering other subject areas in a similar fashion, please visit the Concurrent Engineering course web-site at: http://www.cimwareukandusa.com/All_IE655, and the Total Quality Management course web-site at http://www.cimwareukandusa.com/All_IE673).

As a further example, for course assessment and validation purposes, as well as focusing on the fact, that IT and computing education needs significant changes due to the well known and documented fact, that unfortunately over 75% of software projects fail in industry (ref. www.omg.com). The quality survey asked the following questions from the IT 420 class students:

Please indicate [YES] or [NO]. (Confidentiality will be maintained).
Q1: Do you think a future IT/ networking professional needs to know about the following:
Customer needs and requirements BEFORE a network is designed? [YES] or [NO]
How to collaborate with other companies to jointly develop, deliver and run a networking solution? [YES] or [NO]
Web-based project (assignment in our case) documentation methods? [YES] or [NO]
Understand the processes and constraints involved when developing a computer networking solution? [YES] or [NO]
Understand what communication is? [YES] or [NO]
Understand the challenge of integrating Computers and Computer Controlled Machines and Systems via Networks in digital factories, offices, design studios, banks and other institutions? [YES] or [NO]
Understand the total quality aspects of networking (and in more general IT projects) [YES] or [NO]
Understand the principles of Distributed Processing? [YES] or [NO]
Understand enterprise networking models? [YES] or [NO]
Design enterprise networking models/ process models for the purpose of specifying and then satisfying networking needs? [YES] or [NO]
Know what transmission media are available and what the individual technologies should be used for? [YES] or [NO]
Understand and be able to chose network topologies? [YES] or [NO]
Understand Access Control Methods and Solutions? [YES] or [NO]
Understand Ethernet. Network Architectures? [YES] or [NO]
Understand and chose network protocols? [YES] or [NO]
Understand and chose network services? [YES] or [NO]
Understand Computer Network Reference Models and the OSI seven layer reference model? [YES] or [NO]

Q2: During the remaining portion of the class we are planning to discuss the subject areas listed below. In your view are these important subjects for you to understand and learn?

Some digital factory, and other real-time networking challenges and solutions? [YES] or [NO]
Network Planning and Technology Management? [YES] or [NO]
Network feasibility study? [YES] or [NO]
Network planning strategy (including Internet/ intranet server sites). Network migration strategy? [YES] or [NO]
Network implementation strategy (including Internet/intranet server sites)? [YES] or [NO]
Integrated network planning methods. A summary of network engineering lessons learned? [YES] or [NO]
Some network simulation and analysis tools and methods? [YES] or [NO]

Q3: Do you think a future networking/ computer systems/ IT professional should understand and follow:

• Important IT developments in the world? [YES] or [NO]
• Some of the societal aspects of new networking/IT developments? [YES] or [NO]
• Where the jobs are now and will be in the future, and how to prepare for getting a good, enjoyable job in IT? [YES] or [NO]
• How to innovate and create new IT/networking related products? [YES] or [NO]
• The quality issues of IT? [YES] or [NO]
• How to collaborate over the Internet as part of a project? [YES] or [NO]
• How to document knowledge over the Internet? [YES] or [NO]
• How to make a good presentation to a team? [YES] or [NO]
• How to follow the technical literature and stay ahead of our profession? [YES] or [NO]

To our satisfaction and joy, in April 2002, the NJIT IT 420 Quality Survey Results indicated over 99% approval by the students for the above shown anonymous survey, proving, that they were in agreement with our methods, our approach, delivery, and assessment, and most importantly the need for a fundamental change in the way computing and IT knowledge is educated traditionally, in order to improve the unprecedented 75% software failure rate, that we all experience when using commercially leading products created by market dominating companies.

Summary and Conclusions

In terms of effectiveness in overcoming barriers of academic, student, and other, professional political resistance to change, the Library follows an integrated approach to the analysis of complex, real-world challenges, and then involves a team of engineers, managers, and IT professionals to offer a theoretically sound, as well as practical solution.

Due to the in-depth and quality content, the simple browser readable interface, and the exciting, interactive and powerful 3D graphics, the quality 2D videos, the active code offered for calculations, and the open-source learning/assessment environment offered, learners enjoy the eBook cases and find them more attractive than printed (i.e. passive, non-interactive, non-self calculating, and non-assessing) traditional textbooks.

Our 3D multimedia learning material have been validated and tested in several industry and university (live and virtual) classes, involving hundreds of undergraduate and graduate students at NJIT in Industrial Engineering, Mechanical Engineering, Computing Science and Information Technology, as well as on a wider US and international basis, at Dundee University in Scotland, at Nottingham in the UK, at Imperial College in London, at Old Dominion in the USA, at the University of Michigan, in Ann Arbor, in Sweden, in Hungary, in Mexico, in Hong Kong, in Singapore, in Switzerland, at Kyoto and Kobe Universities in Japan, and at many other institutions and companies world-wide.

We are pleased to report that our methods, and several 3D multimedia resources have been adopted for university and company intranets for eLearning. Due to the open, web-
browser readable nature of our approach, each object/module is customizable, extendible and editable. This popular feature allows students and faculty to become simultaneously authors as well as readers. (In order to maintain integrity and quality, obviously, the core documents are maintained permanently only by the document owners).

The most important design feature of our object oriented system architecture is that there is only one core, reusable electronic document, built of 3D web-objects, and active code, that has to be authored and maintained. This enables a wide variety of users/viewers to occasionally become authors (via the appropriate security gates and web-technology) feeding useful knowledge into the content of the object and component oriented architecture.

This work is the result of several years of on-going research. It started in 1977-78 when Paul G. Ranky has developed an FMS (Flexible Manufacturing System) object-oriented database and then later, in 1984 by Ranky at Nottingham and Siemens-Plessey in the UK, and then in 1992 when together with Mick F. Ranky, supported by CIMware Ltd., http://www.cimwareukandusa.com and FESTO Ltd. an interactive multimedia CD-ROM was developed as an electronic support system for servo-pneumatic positioning, as well as part of another project for bio-medical engineering with Prof. T. Pato in Berne, Switzerland. In 1997 Paul G. Ranky and Mick F. Ranky developed a 3D browser readable, virtual computer disassembly method, supported by industry, that has led to several other R&D grants (including major DOD grants for NJIT) and publications, including the 3D Multimedia Case Based Library (1995 to date).

Since then the topic as well as the architecture has evolved into a robust, object-oriented knowledge management architecture with 3D web-objects, supported by several companies and institutions, including FESTO Inc. USA, GenRad, Inc., The Nottingham Innovative Manufacturing Center, IMI, Ford, Rolls Royce, Ratheon, PSE&G, GibbsCAM, GenRad, Cincinnati Machines, Fanuc Robotics, MCI-WorldCom, IBM, Okuma, BMW, Motorola, Sony, GE Fanuc, Yamazaki Mazak, Bosch and many others. Our efforts have been validated and strongly supported most importantly by our undergraduate and graduate engineering, engineering management and computing students at NJIT, and elsewhere in the world, who have worked through different versions of our objects and helped us shaping it to its current, still evolving, nevertheless already mature and very robust truly multi-platform (meaning Apple Mac, OS 9 and OS X, PC Win 98, 2000, NT, XP, Linux and Unix compatible) format.

We would like to thank for the continuous support of our students, the companies and organizations, and pleased to report that our efforts are moving on with an increasingly positive energy flow in all of us involved.

**Live Software Demonstration**

During the presentation of this paper at the conference there will be several live software demonstrations, illustrating the novel interactive 3D multimedia, as well as the active code
and video-clips, that a printed paper can never truly illustrate. Furthermore during discussions further, in-depth software demonstrations will be given, and questions will be answered during the conference using off-line, and optionally wireless Internet access (based on availability).

Bibliographic Information


[19] Ranky, P G: Reusable, 3D-Interactive Web-browser Readable Case Based Learning Objects and Modules Delivered as eBooks. ASEE (American Society of Engineering Education) NJ Spring Conference, April, 2001 (eProceedings)


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