TEACHING MATERIALS HANDLING VIA MULTI-MEDIA TOOLS

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Abstract: *Materials handling is a vital function in a manufacturing or distribution system. Efficient handling of material allows such systems to operate at high levels of productivity. US companies invest over $90 billion annually in materials handling technology. In this paper, we discuss a multi-media based tool for materials handling engineering instruction. The CD based tool contains three modules. It introduces students to the 'Ten Principles of Materials Handling' and two major categories of materials handling equipment – conveyors and automated storage and retrieval systems (AS/RS). The CD also illustrates industrial applications of major types of material handling devices and teaches the problem solving process through an extensive series of models, algorithms, problems and solutions.*

Index Terms – Multimedia tools, materials handling, education, models and algorithms

INTRODUCTION

Materials handling is fundamental to the productivity of manufacturing and distribution systems [1]. It is a vital function in any manufacturing or distribution systems. US companies invest over $90 billion annually in materials handling technology and systems. The Department of Commerce has identified it as among the fastest growing segments of the world economy. It is therefore important for our universities to prepare materials handling engineers who understand not only the various types of devices, their applications and limitations, but also can put together systems using these devices. The latter requires an understanding of the principles of materials handling and modeling/analytical skills. Materials handling is typically taught as part of a facilities design course. Although there are a few text-books that focus entirely on materials handling, these tend to emphasize materials handling technologies and some operational principles. The text-books on facilities design tend to allot about 20% of the coverage to materials handling topics and emphasize modeling aspects. Thus, to teach the materials handling topic, an instructor often relies on a combination of books, trade journals, magazines, photographs, videos and plant visits to give the student an understanding of the technologies as well as modeling and analytical aspects. Due to the nature of the existing set of educational materials, these typically have to be introduced in a sequence and cannot be easily integrated. For example, it is difficult to discuss analytical or simulation models during a plant visit or when viewing a video or showing photographs. In order to present the technological and modeling aspects in an integrated manner, a fundamental change in our educational approach is needed. This is where a CD based instructional tool could be helpful.

By assembling a team composed of several leading experts in materials handling research and education, a cognitive science researcher with broad experience in evaluating learning environments including learning technologies, a multimedia software development team consisting of programmers, creative multimedia designers, playspace developers, animators and audio/video specialists, we hope to provide materials handling instructors and students a single platform to seamlessly combine descriptive, factual material with analytical models. Strengths of this team include:

- Domain knowledge and teaching experience of three scholars in materials handling.
- Expertise in the application of technology to the educational process.
- Access to state-of-the-art multi-media development infrastructure.
- Access to one of the world's largest knowledge bases of state-of-the-art materials handling technology contributed by member companies of the Material Handling Industry (MHI).
- Close interaction with materials handling engineering practitioners and educators.
- Creation of a feedback loop between assessment of learning technologies through observation of student use of multi-media design and re-design of those multi-media tools for education.

We propose to exploit the above strengths to develop a multi-media based system for integrative instruction in materials handling engineering which can be distributed at very low cost to universities throughout the world via the web and CD-ROM media. The tool is being developed by a truly multi-disciplinary team consisting of technical content and multi-media technology experts as well as communication, learning, evaluation and cognitive psychology experts (see Figure 1). This multi-university team includes faculty and researchers from industrial engineering, electrical, computer and systems engineering, education, electronic arts and media, and cognitive psychology.

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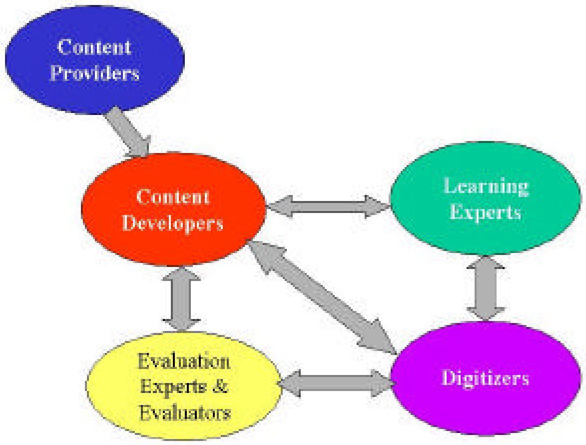

FIGURE. 1
MULTIMEDIA MODULES DEVELOPMENT TEAM

MODULES

Three modules will be developed as part of this project. The first introduces students to the 'Ten principles of Materials Handling'. The second introduces two categories of materials handling equipment and illustration of both in a distribution warehouse setting. The two modules teach the principles as well as the problem solving process through an extensive series of models, algorithms, problems and solutions. They illustrate the creative application of quantitative tools and design problems in solving technology selection and technology analysis problems. The second module system also includes extensive simulations of various dynamic processes involved in materials handling, including animated simulations of real-world implementations of engineering designs. Each analytical model includes variables, including temporal, spatial, mechanical and material ones, which the student can manipulate in order to see changes flow through different configurations of materials handling processes, and in order to achieve optimal arrangements. Software code is implemented to create reliable virtual contexts. These contexts are dynamic, responsive realms containing objects (e.g., virtual MHDs, AGVs) and rules. The virtual test-bed, founded in sound materials engineering thinking, avails the student a truly innovative forum to synthesize theory and practice and to explore questions in a deep and new fashion.

Students will be able to work on the system both synchronously (in the real-time context of the classroom) or asynchronously (at their own pace). Materials will be delivered through the World Wide Web so they can be linked and navigated hypertextually.

TEN PRINCIPLES MODULE

The first module being developed and distributed on CD media focuses on ten basic principles of materials handling. Work on seven of the ten principles as well as information design for all of the ten principles have been completed. The information design was completed with the help of the content development team, coginitive psychology experts and undergraduate students. The information itself is structured in five layers, namely Discover, Explore, Contrast, Extend and Integrate (see Figure 2). Each principle is introduced via the first four layers. The purpose of the Discover layer is to let the user discover a principle on his/her own by watching a situation that to an expert clearly illustrates application of that principle. In this layer, no questions are posed to the learner. Instead, a definition is presented along with a rich animation and video clip of a real world application. The student is only instructed to watch the animation and video clip and make a note of the aspects of the animation and video clip that stand out. A 'notebox' is provided throughout for this purpose - to make notes and to answer questions that are posed in subsequent layers.

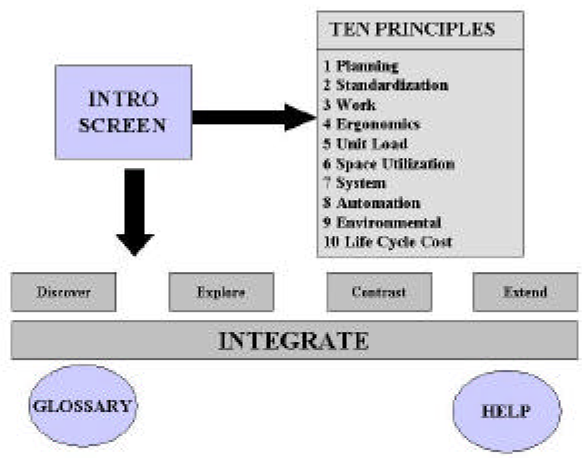

FIGURE. 2
TEN PRINCIPLES MODULE INFORMATION DESIGN

Next, the Explore layer allows the learner to explore the principle in more depth, by examining key aspects of the principle. Each principle has three or more key aspects. In addition to providing text of the key aspects, the explore layer attempts to provide a deeper understanding of the principle by using illustrations, video clips, two or three dimensional animations, an interactive 'play space' and/or questions with answers. For example, a student is posed a question in the Explore layer and asked to note answers in the notebox. To aid the student in answering the questions, multiple perspectives on a particular question are provided. These perspectives, called 'talking heads', include that of a student, professor, field engineer and/or manager. Often, when the learner clicks on a perspective icon, key ideas are reinforced through additional models and theories. The interactive playspace permits the user to interact with a mathematical model, provide input (design) parameters and examine the output of the model, i.e., results provided by the model on the system's performance for the chosen inputs. Although the student does not need to know details of the mathematical model, this may be an appropriate place for the instructor to introduce them if s/he chooses. Our experience shows that after a student interacts with the playspace models, s/he is motivated to learn the principles underlying the model. For example, after interacting with the unit load playspace, the student is motivated to learn how s/he got the optimal answer. This may present a suitable opportunity for the instructor to introduce the cube per order index storage policy. Similarly after intercating with the queuing network model and coming up with a near optimal solution in the animation principle's playspace, the student may be interested in learning more about analytical (queuing network) models and how they might be advantageous compared to empirical (simulation) models. Examples of video clips, animations and playspaces are available at http://www.rpi.edu/~herags/Research/research.html

After gaining a deeper understanding on a principle, the learner is re-introduced to the animation and video clip shown in the Discover layer. This time, a a voice explains details of the animation and video clip. Questions are again posed to help the learner check his/her level of understanding. After the Explore layer, the student is then taken to a Contrast layer, which includes two examples. The first illustrates a proper application of the principle and the second, an improper application. Once again, targeted questions, multiple perspectives and noteboxes are used to help the student understand drawbacks of the improper application, how they might be overcome as well as the good aspects of the proper application.

The Extend layer extends the principle to other domains. All the principles are explained for the most part using the warehouse context. The last layer discusses the same principle in a different context. For example, when learning the space utilization principle, the learner often thinks of how to store unit loads in a high rise warehouse. However, proper utilization of space is etremely important in conutries where there is an extremely high premium on space. For example, automated lifts and robots are used to park cars in tight spaces in a Japanese parking garages.

The last layer, called Integrate layer, is intended to help the learner understand how to integrate the various principles. Design and operational decisions that address a particular principle impact one or more of the other principles. The Integrate layer attempts to provide the learner with an understanding of the issues that impact two or more principles. This layer is yet to be developed and will make use of short cases to reinforce integration aspects.

In addition, a self contained glossary section including all the terms and definitions used in the 'Ten Principles' module will be developed. The current version of the CD ROM containing seven principles is being distributed to practicing members of the MHI and materials handling educators at the College-Industry Council on Material Handling Education (CICMHE) for their feedback. Most CICMHE members are professors in US Universities who teach materials handling education. Evaluation and testing will also take place in the next few months.

CONVEYOR AND AS/RS MODULE

The objective of the Conveyor and AS/RS module is to integrate knowledge of material handling technology with modeling skills. It makes use of self-paced, multimedia supported exercises to increase knowledge of AS/RS and conveyors and illustrates material handling applications of analytical modeling through hands-on design and problem solving. The module is targeted to three groups of individuals - a) intermediate level learners including juniors and seniors in undergraduate engineering programs, b) learners with strong modeling skills, but limited knowledge of technology, and c) working professionals without adequate modeling skills, but strong knowledge of current technology and practice.

Exercises are introduced via a virtual facility which is modeled after a real world distribution center (DC). The DC belongs to a national chain of teen fashion clothing retailer (see figure 3).

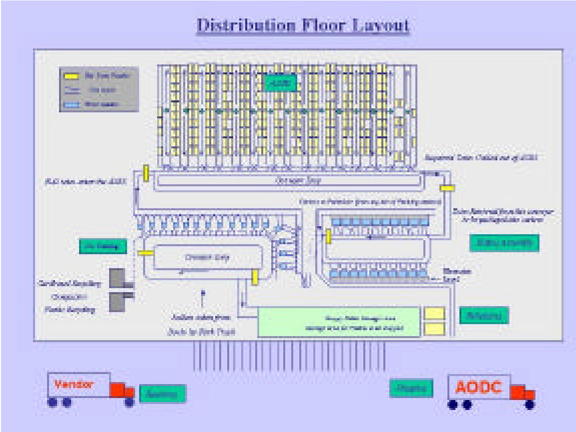

FIGURE. 3
VIRTUAL DISTRIBUTION CENTER

The DC ships to 2250 stores nationwide on a weekly basis. 430 pallets of garments are received on 43 trucks and unloaded daily. 28000 totes containing individual SKUs must be stored in the AS/RS system. 450 store orders must be assembled and loaded on 45 trucks daily. The primary receiving functions in this DC include unpacking, inspecting, and storing Stock Keeping Units (SKUs).

Shipping functions include picking, consolidating, palletizing and dispatching store orders There are several 'areas' in this DC where different material handling functions are carried out. For example, in the deunitizing area, the material flow functions are, receive, unpack, inspect, sort tote and store in the ASRS (see figure 4). Similarly in the kit assembly area, kits must be cartonized and orders assembled; in the pallet storage area, outbound pallets must be staged and shipped.

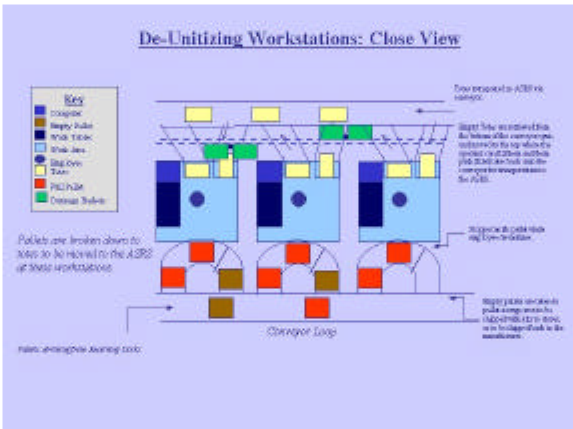

FIGURE. 4
FUNCTIONS IN DEUNITIZING AREA

The pedagogical approach follows three levels of analysis for each of several exercises in each of the five areas. The first level deals with materials handling technology selection and configuration. The second permits progressive design refinement and analysis of unit materials handling operations and the third requires performance based design validation. For example, in the deunitizing area, the level 1 interactive exercises require the user to specify conveyor technology including model selection, carrier Spacing and speed detremination. The level 2 exercises relate to the conveyor operations and focus on planning of secondary handling systems. Level 3 exercises relate to conveyor performance and this is where the student must use analytical models to determine optimal or near-optimal throughput, utilization and cost under different system conditions.

TARGET AUDIENCE

The multi-media developmental effort described in this proposal is expected to be used in 'Facilities Design' courses. This course has a reasonable materials handling engineering component. It could also be used in Masters level courses related to the materials handling topic. Considering the modules have a high degree of probability of being implemented in other institutions, several hundred students are likely to benefit each year. While the target audience is Industrial Engineering students, many aspects of our modules will be of interest to a non-traditional audience, for example, chemical, electrical, materials science, mechanical engineering and business students. A major goal of the multi-media modules development is to integrate the analytical and technology based paradigms of the materials handling field and prepare practicing engineers with the knowledge and skills to design, build and analyze material flow systems of the future. As a result of introducing the CD based tool in materials handling classes, we believe students will have an in-depth understanding of the basic principles of materials handling, types and applications of the two major categories of materials handling equipment as well as hands-on experience in designing and analyzing materials handling systems for specific scenarios.

We anticipate the modules to be used as an additional resource in a Facilities Design class. The could be used in a studio class-room setting to interactively explore the contextual and analytical aspects of the design and operational problems encountered in materials handling systems. As a result of immersing themselves in the modules belonging to an equipment category (discrete materials handling equipment), students will have a better feel for and grasp of the general design and operational problems encountered in such systems.

To summarize, the approach to multi-media module development includes illustration of ten basic materials handling principles, two materials handling equipment categories along with their applications, and development of integrated, interactive models and analysis tools for their design and efficient operation. There will be several iterations of design, evaluation and re-design (based on the feedback received in the evaluation process), before it is implemented and distributed nation-wide.

PROJECT EVALUATION

Formative evaluation will be conducted of each module as it is developed, piloted and implemented in classroom settings. Major components of this stage will consist of the following:

1. INTERVIEWS OF DEVELOPERS AND FACULTY to assess and define assumptions used in development of multi-media tools and to develop base-line objectives and correlatives for future measurement of success for each module.
2. OBSERVATION OF CLASSROOM: Two observers will observe student use of the multi-media based tools in real-time, real-class settings on two occasions to assess usability and instructional viability for each tool. Variables to be included are: level of interaction between instructor and student, frustration cues by student, and barriers to use including hardware and software difficulties, curriculum adaptability, and adaptiveness to alternate learning styles.
3. SURVEY & INTERVIEW OF STUDENT SUBJECTS: A written survey followed by INTERVIEWS will gather data on the following dimensions: student

perception of difficulty of use motivational dimensions, mastery of content, ease of use, barriers to use, and confidence in use of equipment, software, and knowledge.
4. CONVERGENCE BETWEEN INTERVIEW/SURVEY DATA AND OBSERVATIONS including convergence with the program goals.
5. INSTRUCTIONAL TECHNOLOGY REVIEW will be conducted to measure the following technical aspects of each design: Excessive scrolling, Location of information, Navigation including appropriate links to other modules supportive of the exercise, and appropriate use of pedagogical methods. Other areas to be examined will include availability of help for novice and expert users, as well as necessary instructional and curriculum documentation for non-developer instructors to use when reviewing, selecting and ultimately implementing the modules in a non-supported instructional setting.
6. REVIEW OF USABILITY data will be gathered by verbal protocol methods, videotaping user at screen, talk-aloud ("self-narration") method, and stimulated recall.
7. MEASURES OF SUCCESS will be derived by calculating the convergence between goals for each module in pre-design (1, above) and data on them after deployment of each module in the classroom at midpoint of project and at end.
8. KNOWLEDGE AND SKILLS ASSESSMENT will be done to determine the degree of knowledge and skills gained through the use of the modules by comparing two groups of students - a control group exposed to the multimedia courseware and another base group with no exposure. In addition, a comparison of the evaluative responses to the courseware across graduate and undergraduate students, faculty, and practitioners will be made. This will be a formative comparison with the objective of making explicit what (value) the multi-media modules contribute to learners/practitioners with different "levels" of expertise and experience. This would in turn allow us fold back some of the lessons learned into the design process.

The Ten Principles of Materials Handling module is particularly useful in project evaluation. For example, this module could be used to assess and then to contrast learners' (who have and who have not studied materials handling using the multimedia modules) understanding of the "curricular topics" that are the focus of the other module. A second use of this module is in a pre/post assessment design in which students/learners work through this module prior to one (or more) of the other three modules, next work through the multimedia module, and then re-visit the 10 principles. It would be interesting to see what changes, if any, occur. Is understanding of some/all principles more thorough or deeper? Do students "integrate" more readily and more accurately? etc. The idea is to provide students with a method/space to reflect on what they have learned so they will internalize the general principles embodied in the multimedia module contextual problems.

Practicing engineers from MHI member companies and and CICMHE, representing a cross-section of technical specializations in materials handling engineering, will be recruited to evaluate the CD-ROM system. These individuals will rate the project deliverables with respect to their specializations and assess the value added relative to traditional materials handling engineering course outlines, texts and lecture notes.

Faculty members receiving the CD-ROM system will be surveyed to obtain their assessment of the instructional impact of the project deliverable. This will include quantitative and qualitative changes in course evaluations following adoption of the deliverables. The surveys will be repeated for three years after the project period to assess the instructional learning curve associated with using the project deliverables. Faculty members receiving the modules will be asked to distribute a survey of post graduation contact information for students exposed to the project deliverables. After graduation, these students will be surveyed to measure the perceived impact of the deliverables on their job preparedness.

DISSEMINATION PLAN

An instruction manual will be developed in on-line and paper format so that users of the modules will know how the modules fit within a materials handling course and how they supplement texts and other resources already available. In addition, the manual will describe in detail how the modules are to be used. The final product will then be disseminated via the MHI and CICMHE on CD-ROM and the web.

The MHI product catalog will be the major vehicle for disseminating the completed modules. Through its semi-annual MHI meeting, bi-annual colloquium and teacher training workshop (at which materials handling educators are trained in results from state-of-the-art research and practice), MHI has developed a close relationship with the nation's practitioners and educators in materials handling.

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