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Innovative Educational Tool for Learning Materials Handling Principles, Concepts, Equipment and Analytical Models

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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 $60 billion annually in materials handling technology. It is therefore extremely important for Universities to prepare materials handling engineers who understand the principles of materials handling, as well as the design, implementation, operation and control of materials handling systems (MHSs) so that they can assure the cost effectiveness of this investment. In this paper, we describe efforts underway to develop an interactive, multi-media based system for use in materials handling classes. Modules in the system introduce students to: the ten principles of materials handling, and two major equipment categories - conveyors and automated storage and retrieval systems. They illustrate industrial applications of material handling equipment and teach the problem solving process through a case study and an extensive series of models, algorithms, problems and solutions. The modules can be distributed at a nominal cost to US and international universities via the web and CD-ROM media.

I. Introduction

Materials handling is fundamental to the productivity of manufacturing and distribution systems[1,2, 3]. It is a vital function in any manufacturing or distribution system. US enterprises invest over $60 billion annually in materials handling technology and systems. The Department of Commerce has identified materials handling as among the fastest growing segments of the world economy. It is therefore extremely important for Universities to prepare industrial engineers who understand the principles of materials handling, as well as the design, implementation, operation and control of materials handling systems (MHSs) so that they can assure the cost effectiveness of this investment. Our educational programs must be at the leading edge of both the theories and technologies supporting the design and specification of MHSs.

Unfortunately, the traditional instructional approach fails to convey the flexible modeling and research skills combined with the highly detailed contextual information and technology alternatives needed for effective professional practice. It fails to provide students with an opportunity to develop the necessary engineering judgment and intuition exhibited by experienced professionals who integrate technology selection with engineering analysis in a simultaneous process tailored to individual problems. Standard technology and analytical methods are often modified in unique ways to accommodate individual applications[4]. The traditional approach to materials handling education rarely develops an understanding of this process in the student. As new technologies and analytical tools are developed, we generally make incremental changes in existing courses which tend to increase the density of material and decrease the degree of integration of course topics. A fundamental change in our approach is needed today to meet the challenges of the twenty-first century [5].

This paper discusses our attempt, as educators in materials handling engineering, to integrate the analytical and technology based paradigms of the discipline. It discusses our efforts in finding: (i) ways to eliminate the wall that separates design/analysis tools from their applicable technologies, and (ii) to prepare practicing engineers with the knowledge and skills to design, build and analyze the material flow systems of the future.

We hope to provide instructors and students with a single platform to seamlessly combine descriptive, factual material with analytical models. A multi-media based tool consisting of three modules is being developed at Rensselaer Polytechnic Institute, with support from the National Science Foundation (NSF), the Materials Handling Industry (MHI), College Industry Council on Material Handling Education (CICMHE) and a number of companies in the United States and abroad.

Via the three modules, 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). Material is also being formatted so that it can be delivered through the world wide web as well as CD media. In fact, beta versions of the 'Ten Principles of Materials Handling' and ‘AS/RS and Conveyor’ modules are already being distributed to universities throughout the United States and overseas via the CD-ROM media.

II. Ten Principles Module

Although the multimedia system consists of three modules, this paper discusses only the first in detail since this has been digitized and coded to a significant extent. The module is titled 'Ten Principles of Materials Handling'. MHI has expressed interest in such an interactive training tool and will be designed to accommodate self-paced learning of the ten principles. It will address questions such as: What is the principle? How, where and when should it be applied? When should it not be applied? What are the benefits if it is correctly applied? What may result if incorrectly applied? The 'Ten Principles of Materials Handling' module is currently being developed and distributed on CD media for feed-back and evaluation purposes. Work on the ten principles, as well as information design for the Introduction and Integrate layers have been completed (Figure 1). The information design was completed with the help of the content development team, cognitive psychology experts and undergraduate students. The information itself is structured in five layers, namely Discover, Explore, Contrast, Extend and Integrate. All the layers include rich media including, text, voiceovers, animation, video clips, play spaces, and interactive question/answer format. In the Discover layer, the user discovers a principle by watching a situation that illustrates application of that principle. The Explore layer allows the learner to explore the principle in more depth, by discussing key aspects of the principle. The Contrast layer includes two examples, one illustrating proper application of the principle, and another illustrating improper application. The fourth layer, Extend, extends the principle to other domains.

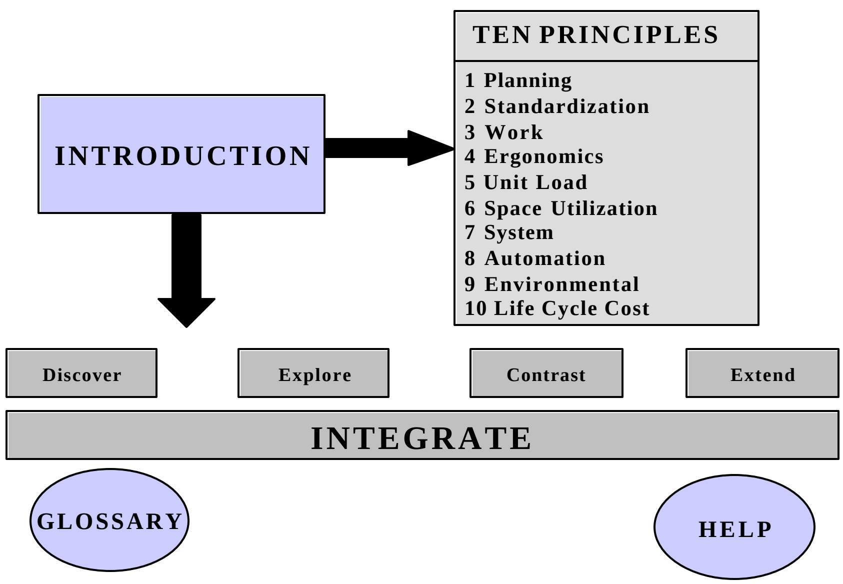

Figure 2 Ten Principles Module Information Design

When the CD is launched, the user is taken to the Introduction screen from which an introductory video containing a message from the project director can be launched. The bottom of this screen has icons that allow the user to proceed to the:

- goals and objectives screen
- CD navigation screen that includes animated demonstrations illustrating how a user can navigate through the various principles, layers, glossary, re-accessing the introduction layer, previous/next buttons seen on each screen, turning the music on or off, exiting from the CD, etc.
- Learning screen that explains (again using animated demonstrations) in detail purpose of the various layers, how to use the playspace, notebox, multiple perspectives feature and various media launches.

The Introduction layer explains there are several ways of entering the 'Ten Principles' module. Depending upon interests, background experience, and study requirements, the learner can choose a sequence that fits his/her needs. For example, a learner can view the principles in any order, move freely between layers in any order within each principle and within each layer, move from one principle to another.

The information design pertaining to the ten principles is structured in five layers, namely *Discover, Explore, Contrast*, *Extend* and *Integrate.* 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.

Next, the *Explore* layer allows the learner to explore the principle in more depth, by examining key aspects of the principle. 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 or even an interactive ‘play space’. The latter 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. The animation and video clip shown in the Discover layer are again displayed with a voice explaining details of the animation and video clip. The student is posed a question at numerous times 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 manager. Often, when the learner clicks on a perspective icon, key ideas are reinforced through additional models and theories.

After gaining a deeper understanding on a principle, the learner 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 from a different context. For example, when learning the unit load principle, the learner often thinks of the unit load as a pallet containing cartons that are being transported to a high rise warehouse. However, the unit load in another context could be something that is totally different. In the case of a recent, well publicized event, the unit load was a cage containing a giant panda bear.

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 the ten principles is being distributed to members of CICMHE and other practitioners and materials handling educators for their feedback. Most CICMHE members are professors in US Universities who teach materials handling education. Evaluation and testing is also taking place in the class-room.

III. Conveyor and AS/RS Modules

The second effort has focused on the development of modules for conveyor and AS/RS. These modules are being jointly developed using a virtual distribution center (DC) concept that provides supporting application context for a wide range of modeling exercises (see Figure 1). The distribution center is modeled after the Eastern Distribution Center of a major fashion apparel retailer with approximately 1,500 retail stores nationally. This facility receives garments in bulk shipments from worldwide suppliers, de-unitizes them and prepares palletized, weekly shipments to individual stores referred to as "kits". Students are introduced to the flows and functions of the facility through a storyboard that follows the movement of materials from unpacking/inspection, staging in temporary storage prior to kitting, retrieval for kit assembly and movement of kit pallets from assembly to shipping.

The pedagogical approach follows three levels of analysis for each of several exercises in 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 determination. 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.

Distribution Floor Layout

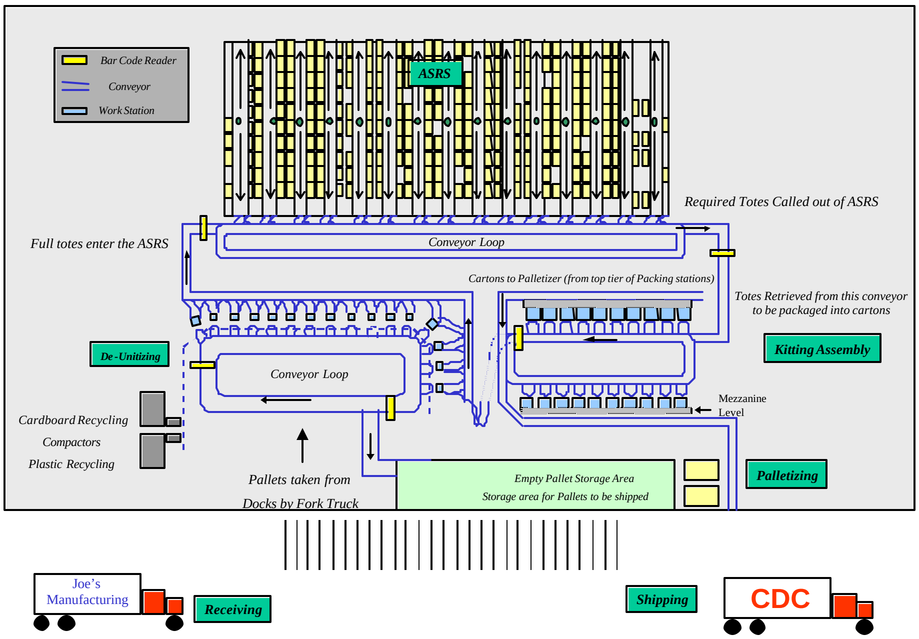

Figure 1. Typical distribution center

IV. Target Audience

The multi-media developmental effort described in this paper 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. 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. In addition, practicing materials handling engineers, who are relatively new to the field are likely to be major users of the products. The CD could be used in preparing for certification exams.

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.

Formative evaluation will be conducted of each module as it is developed, piloted and implemented in classrooms settings. Major components of this stage will include, interviews of developers and faculty, observation of classroom, survey and interview of student subjects, convergence between interview/survey data and observations, instructional technology review, review of usability data, measures of success knowledge and skills assessment.

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 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 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. In addition, based on resource availability, we will maintain a constantly updated web-site. This web-page will contain the developed modules and literature relevant to the modules.

V. Acknowledgement

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Bibliography

1. Heragu, S.S. *Facilities Design*, Boston, MA: PWS (1997).
2. Askin, R.G., & Standridge, C.R. *Modeling and Analysis of Manufacturing Systems,* New York, NY:Wiley

(1993).
3. J.A. Tompkins, J.A. White, Y.A. Bozer, E.H. Frazelle, J.M.A. Tanchoco and J. Travino (1996), Facilities Planning, Second Edition, Wiley, New York, NY.
4. J. Koenig (1980), "Planning and justifying a material distribution center", in Proceedings of the Spring Annual IIE Conference, Dallas, Texas.
5. Editor (1997), "The New University", Business Week, December 12, 1997.

BIOGRAPHIES

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