01 Jan 1994

The Integration of Simulation and Reality for Education Enhancement and Training

Clarence Rasquinha

Stephen A. Raper
Missouri University of Science and Technology, sraper@mst.edu

The Integration of Simulation and Reality for Education Enhancement and Training

Clarence Rasquinha[1] and Dr. Stephen Raper[2]
University of Missouri - Rolla, Missouri 65401
1. Clarence Rasquinha is a Ph.d. candidate in the Department of Engineering Management
2. Dr. Stephen Raper is an Assistant Professor in the Department of Engineering Management

Abstract

Quite often, when engineers are exposed to a manufacturing environment on the job for the first time, they undergo a baptism by fire. The environment forces them to deal with situations that integrate many different bodies of knowledge. Reliance on concepts acquired in the academic environment is crucial to their success. Unfortunately, lacking in most academic environments, is any experience through which some or all of these concepts are integrated. In a continuing effort to enhance educational practices in Manufacturing\Systems Engineering programs and perhaps improve the preparedness of a young engineer, the CITE (Computer Integrated Technological Enterprise) tool offers educators a mechanism through which several important concepts can be integrated and presented to students in a meaningful way.

Introduction:

Relatively recent and conflicting reports regarding the state of the manufacturing base, jobs etc., in the U.S., has led higher education to refocus their attention on manufacturing education. For example, Jasinowski reports that a recent recalculation of U.S. GNP found that manufacturing's direct share of the economy was 23.3% by 1988, higher than it has ever been since post-World War II [14]. This report may be misleading because as of 1991, the Bureau of Economic analysis began using the Gross Domestic Product (GDP) as the primary measure of growth for U.S. production and based upon this measure, from 1970-1992, the percentage of goods (durable & non-durable) produced as a share of the GDP has not only dropped (46.3% vs. 38%) steadily but is also being eclipsed by services offered (43% vs. 54%) [33]. This report indicates that the manufacturing and production base is leaving U.S. shores. Perhaps, academic institutions in the U.S. have noticed this trend and have encouraged the development of manufacturing\systems engineering programs. This steady and perhaps healthy growth in undergraduate and graduate programs in these disciplines across the country is one way to promote research and technology development and may ultimately reverse any negative trends [11], [10]. Furthermore, with the emergence of Computer Integrated Manufacturing (CIM) and several derivative new technologies, several oases of knowledge exist and students must at least be made aware of them [4], [34].

A Manufacturing or Systems Integration Engineering program is uniquely suited to address much of this technology and knowledge. Universities and colleges in the U.S. must always be aggressive in attracting bright students by offering strong and innovative programs in these fields. In the attempt to develop a unique curricula in Manufacturing and Systems Integration Engineering, the curricula must address the concerns noted earlier and should integrate several bodies of knowledge. In a sense, this type of degree mixes many portions of traditional engineering disciplines (EE, ME, ChemE, MetE, etc.) into one discipline. Traditional disciplines tend to emphasize more design\analysis over experimentation\synthesis. So in these disciplines, to a certain degree, it is not as important to build a product or develop a process as it is to design the best product or process. Perhaps by reflecting upon a possible industrial scenario, a further appreciation for a synthesis approach can be gained. Just by introducing a sophisticated robot on the factory floor, manufacturing is not necessarily enhanced. This is because not only is the factory floor physically changed but perhaps the worker\s associated with the robot will have to be educated and business functions such as accounting will have to be updated to reflect the addition of the robot [20]. Thus when an integrated manufacturing situation is considered, not only is design, engineering and production knowledge etc., important but accounting, marketing, finance and quality knowledge etc., is also important. Thus from being able to market the product,

0-8186-6510-6/94 $4.00 © 1994 IEEE

develop a cost structure for the product, design the product for manufacture, developing process plans for the product, inculcate an active quality control structure for the product, produce the product, assemble the product, package the product, deliver the product in usable form to end-users and reclaim the product at the end of its life cycle, these and other areas of knowledge must be articulated to the student. Almost all of these areas require or are enhanced by laboratory components [21]. Many of these topics are presented to the student but no opportunity is provided where all these topics become integrated and dependent on each other. One is lead to believe that this knowledge can only realistically be gained through work experience over many years in industry, the ideal environment for integrating one's education. However today's engineers are generally expected to perform well from the first day on the job and performance is based upon their familiarity of the limited topics that are presented while in school. In preparing them for this demanding work environment, perhaps it would be best to develop a business, a real world company within the university setting. However, in business one does not experiment and evaluate the results at the risk of running the business into the ground and so to experiments that demonstrate principles in marketing, manufacturing, quality, etc. may expose a university-based company to undesirable risks. These risks may be too great for a university or department to bear even at the expense of providing the ideal educating experience. Furthermore, students need a safe environment where they can use their knowledge without suffering any adverse consequences from poor decisions and get some exposure to industrial facilities\equipment.

A suitable alternative to a university-based company can be accomplished by the integration of Simulation and Reality, the concept of a Computer Integrated Technological Enterprise or CITE. This concept provides students with the tools to manage and operate a fictitious company (with real information) in a user friendly, safe and integrated environment. CITE combines a business simulation with a manufacturing simulation and an automated packaging line comprised of industrial grade equipment. Similar applications (combining simulation with hardware) are found in aircraft companies that are involved in improving the designs of transport aircraft, where computer simulations are being used to model humans and then are integrated with a real cockpits, seats etc., [28]. The U.S. Navy has been involved in developing pilot training programs that use embedded training, allowing for the combination of simulation to be integrated to the physical aircraft [9]. Simulation (and animation) can be used to not only realistically show board room decisions but also manufacturing complexity. However simulation alone is not enough in an engineering education. Engineering education, specifically, Manufacturing or Systems Integration curriculum must include a heavy dose of hardware-based laboratories. It is not possible to get one's hands dirty with a simulation and animation. Thus a unique combination would be to integrate simulation with real hardware from which various laboratory studies\scenarios may be carried out. This combination presents students with a "close to real" experience before graduating and acquiring the real stuff. Note that the authors do not suggest that this unique combination of simulation and reality is an alternative to actual job experience, only that it can be a useful tool in preparing students for the great challenges they will face upon joining industry. Therefore, in the development of innovative courses within a Manufacturing and Systems Engineering program, a possible capstone course could be one which provides students with a intellectually challenging environment that integrates some, if not all, the crucial concepts in a manner that might be expected in industry.

Four distinct phases were identified as important to the successful development of CITE [24]:

I) Development of the business functions within the information cycle of a typical manufacturing firm.

II) Development of a model that accurately portrays the factory operations of a manufacturing firm.

III) Development of the Packaging Line (reality) that incorporates industry donated equipment and

IV) Integration of Business functions, Simulated Manufacturing activities and the Packaging line.
To date, all but parts of phase IV have been completed.

The following paragraphs provide a short description of the business, manufacturing, packaging and how these distinct phases are all integrated and presented in a user friendly environment. Note that a significant amount of time must be spent on preparation by the student groups before they interact with each of the following environments.

CITE Business Environment:

This environment is provided through the use of a business game. In essence, a business game is a business simulator. As of 1987, over 8500 instructors in over 1500 4-year business schools have used business games in course work [16]. In addition to frequent use in colleges and universities, many large firms use business simulators as part of a training program administered by management service organizations. In CITE, goals are specified by the administrator for a fictitious company, ACME Inc. and students attempt to achieve these goals. As most business simulators are written by business school faculty, their mode of instruction is similar to engineering schools, i.e., student textbooks and handbooks for the specified software are provided. Students are guided through and explore the changes to a variety of inputs to the game. Thus students not only see, they interact with the software. In CITE, students will play the role of running ACME, Inc., in teams. Students are exposed to a balanced number of decision variables in such areas as R/D, production, finance, accounting, marketing, etc. Pray & Methe believe that a need exists for students to experience some issues of technology management and using or incorporating technological change in the simulator [22]. While addressing the above mentioned decision variables and some aspects of technology management, it is also important to use a package that is neither simple nor overly complex. Generally, packages that offer 30 or less decisions/session are considered simple [16]. Five business simulators were evaluated for use in CITE, they included: The Executive Game [13], Corporation [31], The Multinational Management Game [15], Modern Business Decisions [6] and The Business Policy Game [5]. Based upon the evaluation criteria mentioned earlier, the Business Policy Game (BPL) was chosen. ACME Inc. is portrayed as a company that is involved in the manufacturing and packaging of a hi-tech family of products, within a flexible manufacturing facility. This is one of many ideal depictions, in keeping with the goal of developing an innovative program.

Time spent on preparation includes a thorough, page-page reading of the student manual and any other information the provided by the administrator. Goals are specified by the administrator and can be short or long term. At the end of each business encounter (one business quarter), a copy of each group's decisions and results may be printed. The report is quite extensive and gives the student group a mechanism for developing a business plan for the next quarter. All the ground rules regarding, how many encounters with the software, what if any changes permitted, etc. can be set and regulated quite easily. Due to the modular nature of the software developed, the administrator can replace the business game with any alternative game with relative ease as well as change the historical data that initially comes with the game so as to cater to real manufacturing environments that exist and for which business data is readily available.

CITE Manufacturing Environment:

The use of simulation models for the purpose of teaching engineers in academia is common and dates back a few decades. Many researchers are showing a renewed interest in sophisticated model building and study [26], [27], [1]. Model development of an existing Flexible Manufacturing System (FMS) was conducted using SIMAN\CINEMA, a general purpose simulation and animation package [23]. Two objectives were identified in this phase: a) Students must get exposure to the operations of simple-complex flexible manufacturing facilities that are in operation today and b) they must be able to make justifiable changes to the operations of the FMS they study. Although some state of the art Flexible Manufacturing Facilities are kept confidential for the fear of duplication, there is enough literature available for modeling different flexible facilities at each offering of CITE [32]. An added bonus of this phase is the ability to model the FM Cell that is housed in the Computer Integrated Manufacturing and Packaging (CIM\P) laboratory in the Department of Engineering Management at UMR. Eventually, it is intended to offer a menu, from which the student group may choose a FMS that most appeals to them, for study. As mentioned earlier, the student groups must have come prepared i.e. collected literature about the facility, the products, etc., (process plans, part programs, etc.).

An FMS (Cessna Plant) was arbitrarily selected from available literature and was further embellished by the author due to a lack of complete information [3], [17]. A combined (parts of the model are both discrete and continuous) model was developed and then at a later date was animated. Based upon the results of their business projections, the student groups must be able to meet production for the quarter. The model was developed to accept certain information (simulation duration time, attributes, operating times in terms of parameters for statistical distributions, etc), which must be known to the student group\user. Prior to the model being run, the user is queried for the time duration of each simulation run, machining times for parts that are manufactured in ACME's plant and assembly and ultrasound wash times. The duration time for each simulation run is in entered in multiples of 7200 minutes (3 shifts\40 hour week), the machining times for the parts are entered in terms of the parameters for a triangular distribution and the times for assembly and ultrasound as constant. This information is saved to a file and then opened and read by the model. The animation reflects both a static layout as well as a dynamic layout. The user has the option of conducting the simulation either with or without the animation. A simulation run without the animation is significantly quicker than a simulation run with the animation.

By no means does the model request all the information that can be provided by the user, at this stage of development. Several authors have developed simulation (no animation) models which can be built by user input, noting that the static portion of the model is generally fixed and only a variety of attributes may be added or left off [35]. Furthermore, when an animation of a facility is used in conjunction with the simulation, as in CITE, model development becomes complex if the animation is to reflect all the features and changes after every simulation run. Perhaps some tradeoff between user input to the model and what is reflected by the animation, will have to be tolerated. A copy of the simulation output may be printed.

CITE Packaging Environment (Reality):

The development of the automated packaging line is the third critical challenge in the development of CITE. This phase identifies the "reality" or hardware part of the CITE project. Note that this phase can also include other manufacturing operations, however a packaging line was selected to address the needs of packaging courses offered by the department as well as to demonstrate that the packaging function is becoming an integral part of modern flexible manufacturing systems [34].

In order to present a plausible and logical connection between manufacturing and packaging, ACME Inc.'s, packaging line packs (fills, labels, caps, weighs, etc.) the manufactured products with a granular product for weight balance. Note that such explanations can be changed whenever new and different equipment becomes available and gets on line. As the Engineering Management department is committed to furthering packaging education, this packaging Line will serve to enlighten students regarding packaging machinery and their integration into a line. Several bodies of knowledge are exposed here, they include and are not limited to: a) studying line efficiencies, b) Reject analysis (unstable caps\poor labels\incorrect weight, etc), c) efficient conveying strategies (mechanical conveyors vs. air conveyors), d) conduct statistical analyses e) cap torque analysis, etc., [19]. Students will be required to suggest, justify and make improvements to the line. Future enhancements to the line may involve Vision systems, Bar-Code systems, etc.

All the equipment that is being used in the line is off industrial grade and was donated by major players in the packaging industry. The Packaging Line is comprised of an Unscrambler, Filler, Weigher, Capper, Labeler, Accumulator and modular Conveying that is placed in an optimum fashion, both in terms of easy access and layout. All these machines are currently in the laboratory, save for some minor modifications that will put them in working order. The filler and weigher offer some software control of on-board functions. These include auger revolutions, timed indexing of containers, taring of containers, average weight calculations, etc. The unscrambler, accumulator, horizontal labeler and capper do not offer any software features and generally provide just for on\off switching. Additional modifications to the equipment will come about through the use of sensors (retroreflective, etc.) and pneumatic cylinders, just to name a few. In addition to both the accumulator and the unscrambler requiring their channeling\guides to be modified\built, some channeling between all the machines and the common conveyor is required. The capper is a hi-speed machine that has a hopper for the caps, a mechanism for placing the caps in the correct orientation over the bottle and five rotating heads that torque the cap onto the bottle. The capper can be outfitted to handle several sized caps and bottles. Due to the modular nature of the conveyor, which conveys the closed bottle to the labeler and then to the weigher, a certain degree of flexibility is achieved in terms of line layout. Future developments include the installment of a communications card in the expansion slot in the weigher which can be than be used to send weight data to the computer via a RS-232 port. Furthermore, the filler has a RS-232 port that can receive weight data and use it to make corrections (if needed) to the number of auger revolutions. Upon implementing the necessary software and hardware, the promise of an active control loop between the weigher and filler holds true. Last but not least, an automated material handling system will be developed to place product into the filler's hopper.

CITE Integrated Environment:

All software development was conducted in an MS-DOS environment (IBM model 70, 386). Through the use of batch files, and executable programs written in Microsoft Quick Basic, a menu based, user-friendly package was developed and is operable in the laboratory. The menu allows students to select any of the three environments described earlier. Although the menu allows for a random selection of the environments, it is recommended that students first select the business environment, manufacturing environment and finally the packaging environment. Both the business game and simulation package are accessible through executable files. In the packaging line, the unscrambler, filler and weigher are controlled (off\on) through a Data Acquisition Card (DAC) installed in the PC. The 8255 I\O chip on the DAC allows for the control of two eight bit output ports and one eight bit input port. Circuits were designed and built in-house to interface with the chip, so that any inputs (sensors, solenoids, etc) and outputs (relays) can be controlled through the PC. A bank of 16 LED's and 8 switches mounted on a panel mount cabinet inform the user about the status of any output or input at any given time. The programming language of choice for the DAC is Microsoft Quick Basic. Literature, regarding the control of packaging and other such equipment, suggests extensive use of programmable logic controllers (PLC) [8]. Although a PLC can be easily configured to control (on\off) this equipment, if any data acquisition is to be conducted, a data card must be used in conjunction with the PLC. This, in effect, performs the same function as a data acquisition card. Previous familiarity with a DAC inclines the author toward its use [25].

Currently, due to memory constraints, CITE is only offered as a stand alone package. Development of a networkable version of this package with the ability to emulate the automated packaging line, is intended. Currently, the PC, monitor, output\input detectors, circuit boards, power supplies, etc. are all housed in a full size mobile panel mount cabinet.

Conclusions:

The success of CITE will largely depend not only on the individual phases described above, but on the smooth transition between the phases. Additionally, the authors are hopeful of obtaining FMS and business information from prospective employers on campus to use in CITE. Perhaps this will allow for further preparation of students in advance of joining their employer. Upon completion of a functional package, it is intended to offer CITE as a course and conduct an evaluation of its benefits. A means for accurately measuring the educational benefits of CITE and similar tools is critical to its continued use and eventual acceptance in teaching environments.

An ideal operating environment in which to offer CITE would be a multitasking\open environment and this should be possible in the foreseeable future [7], [18], [30], [29] [12]. To a certain degree, it can be argued that CITE reflects trends in industry, as several major corporations in the U.S. have taken great strides in developing an open-systems environment as a means of gradually moving from the old way of doing business to the Computer-Integrated Enterprise [2].

References:

1. Barton, R and Scruben, L. "A New Graduate Course: Using Simulation Models for Engineering Design", Proceedings of the 1992 SCS Western Simulation MultiConference on Simulation in Engineering Education, January 1992, 297-301.

2. Boudette, Neal E. "Creating the Computer-Integrated Enterprise", Industry Week, June 1990, 43-66.

3. Carrie, Allan. Simulation of Manufacturing Systems. London: John Wiley & Sons, 1988.

4. Comerford, Richard (Senior Editor) and others. "The Flexible Factory: Case Studies\Manufacturing a La Carte", IEEE Spectrum, September 1993, 28-42.

5. Cotter, V.R. and Fritzsche, J.D. The Business Policy Game. 3rd Edition. New Jersey: Prentice-Hall, 1991.

6. Cotter, V.R. and Fritzsche, J.D. Modern Business Decisions. New Jersey: Prentice-Hall, 1985.

7. Davis Jr., Don H. "Perspectives on Open Systems", Industrial Computing, June 1991, 26-27.

8. Dejean, David, M. "Packaging Line Monitoring - What you don't know - Will hurt you", Presented at the Conference of Successful Applications of Automated Packaging Systems under the auspices of SME and PMMI, June 1991.

9. Dornheim, Michael,A. "Low-Cost Simulation likely to reshape market", Aviation Week & Space Technology, September 1991, 38-41.

10. Ehmann, K and Jones, Philip. "Master's Programs and more\Training for Manufacturing\Manufacturing a La Carte", IEEE Spectrum, September 1993, 76-81.

11. Erevelles, Winston. "A Taxonomy-Based Design Methodology for CIM Laboratories in Engineering Education", Ph.D. Dissertation, University of Missouri-Rolla, 1992, 1-32.

12. Galane, Michael. "Open Systems: Uniting or Dividing the Organization", Industrial Computing, June 1991, 22-25.

13. Henshaw, R.C. and Jackson, J.R. The Executive Game. 5th Edition. Illinois: Irwin, 1990.

14. Jasinowski, Jerry. "Manufacturing's Renaissance", Industry Week, April 1991, 63.

15. Keys, B. et al.. The Multinational Management Game. 3rd Edition. Illinois: Irwin, 1992.

16. Keys, B. and Wolfe, J. "The Role of Management Games and Simulations in Education and Research", Journal of Management, vol. 16, 1990, 307-336.

17. Kochan, Anna (reporter). "Cessna FMS enters production", The FMS Magazine, April 1985, 87-88.

18. Kuhn, D. Richard. "IEEE's Posix: Making Progress", IEEE Spectrum, Dec 1991, 36-39.

19. Lenox, S. and Wright, C. "Increasing Packaging Line Efficiency Through Air Conveyors, 1991", Presented at the Successful Applications of Automated Packaging Systems under the auspices of SME and PMMI, June 18-19, 1991.

20. Mckenna, Joseph. "The Robot's Here, Now What Do We Do ?", Industry Week, June 1990, 93-94.

21. Omurtag, Yildirim. "Computer Integrated Technological Enterprise: Combining Computer Simulation and Reality for Improving Manufacturing Engineering Education", Working Paper, 1991.

22. Pray, T. and Methe, D. "Modeling Radical Changes in Technology Within Strategy-Oriented Business Simulations", Simulation & Gaming, vol. 22 1991, 19-35.

23. Pegden, C. Dennis, Shannon, R and Sadowski, R. "Cinema IV Research System", Systems Modeling Corp., 1992.

24. Raper, S., Rasquinha, C. "A Conceptual Approach For Engineering Management Laboratories: Combining Simulation with Physical Reality", Proceedings of the Annual ASEE Conference, July 1993, 1640-1643.

25. Rasquinha, Clarence, A. "A Prototype Intelligent Process Controller For The Small Manufacturer", Master's Thesis, University of Missouri-Rolla, 1990, 19-31.

26. Sethupathy, T. and Ballard, J.L. "Simulation Model of a Teaching Flexible Manufacturing Cell: An Integrated Approach", Proceedings of the 1992 SCS Western Simulation Multiconference on Simulation in Engineering Education, January 1992, 245-249.

27. Schwer, Avery. "Simulating Industrial Environments to Enhance Student Understanding of Manufacturing Concepts", Proceedings of the 1992 SCS Western Simulation Multiconference on Simulation in Engineering Education, January 1992, 82-85.

28. Scott, William, B. "Computer Simulations Place Models of Humans in Realistic Scenarios", Aviation Week & Space Technology, June 1991, 64-65.

29. Sheridan, J.H. and Teresko, J. "Open Systems: Gateway to a New Computing Age", Industry Week, April 1991, 25-56.

30. Simmons, Peter C. "PPCU (Partial Payload Checkout Unit)". IEEE Potentials, February 1992, 33-35.

31. Smith, J.R. and Golden, P.A. Corporation: A Global Business Simulation. 2nd Edition. New Jersey: Prentice Hall, 1994.

32. Talavage, Joseph and Roger Hannam. Flexible Manufacturing Systems in Practice. New York: Marcel Dekker, 1988.

33. U.S. Bureau of the Census, Statistical Abstract of the United States: 1993. (113th edition), Washington DC., 1993, 437-445.

34. Zygmont, Jeffrey. "FMS Underlies Modern Trends In Manufacturing", Managing Automation, April 1993, vol. 8, No.4, 20-22.

35. Zimmers, Emory, W., Jr. and Valenzuela, Carlos, A. "Building a Flexible Manufacturing System (FMS) Simulation in a PC Environment", Proceedings of the SME sponsored Conference of Simulation and Artificial Intelligence in Manufacturing, Oct 1987, 1_123-1_135.