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Educational Computer Integrated Manufacturing (CIM) Labs in Turkey: A Field Study*

MUSTAFA YÜZÜKIRMIZI
Kirikkale University, Dep. of Industrial Engineering, 71450 Yahsihan, Kirikkale, Turkey.
E-mail: myuzukirmizi@kku.edu.tr

Constantly advancing technology is getting more rapid, integrated and flexible. Today's cutting-edge technology in manufacturing where the entire production process is controlled by computers is specified as a Computer Integrated Manufacturing (CIM) system which differs from traditional manufacturing technologies in processing, equipment and methodology. It is, therefore, important to educate potential engineers with the necessary skills required in today's technologically developed industry. In this study, CIM laboratory settings and applications in Turkish engineering education are surveyed in an investigation of the curricula used in these laboratories. In this context, the CIM curriculum in Kirikkale University is described. Improvement areas in CIM education and usage of laboratories are discussed. The overview of this curriculum will serve as a framework in curriculum design and give important ideas on improving the curriculum for institutions that already have CIM laboratory or are considering setting one up.

Keywords: engineering education; computer integrated manufacturing; virtual manufacturing

1. INTRODUCTION

AUTOMATION IS A SYSTEM of manufacturing designed to enable machines to perform specific tasks formerly done by humans, and to control sequences of operations without human intervention. To stay competitive, factories are increasingly automating their production lines. Today's state-of-the-art technology in automation of manufacturing lines is Computer Integrated Manufacturing (CIM) systems. A CIM system can be easily modified to process different parts and manufacture various products; thus, it is also called a Flexible Manufacturing System (FMS).

The evolving manufacturing environment characterized by global competition and rapid changes in manufacturing processes and related technologies requires creation of education systems that are easily upgradeable and into which new syllabuses and functions can be readily integrated. This new environment calls for advanced equipment, hands-on experiences in laboratories that have modularity, integrateability and customization. There is also an emphasis on interdisciplinary studies, teamwork, innovation and leadership as part of the new curricula in engineering education. This paper discusses these concepts and presents ideas for the usage of labs to support new curricula.

2. RELATED LITERATURE

A large number of definitions of CIM can be found in publications associated with CIM [2, 17, 25]. To summarize, CIM, in engineering, is a method of manufacturing in which the entire production process is controlled by computers. In a CIM system, functional areas such as design, analysis, planning, purchasing, cost accounting, inventory control, production, material handling, quality control and distribution are linked through the network of computers. With CIM automation, manufacturers can produce smaller batches of more varied products. By implementing CIM systems, companies can shorten their manufacturing processes through improved operational control, round-the-clock availability of automated equipment, increased machine utilization and responsiveness and reduction of human intervention.

Today, developed countries have considerable experience with CIM and have progressed various integration concepts. In a survey conducted by Kimble and Prabhu [9] in 1988 among English manufacturers, 58% of the respondents had some form of CIM. Also, an attempt is being made to utilize well-trained engineers, managers and craftsmen and to integrate them into the CIM system.

CIM laboratories and related literature can date back to the 1980s in advanced countries [22]. Alptekin, Benjamin and Omurtag [1] describe a model CIM program developed by the Department of Engineering, University of Missouri-Rolla USA.

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Table 1. Equipment of respective CIM la

	Galatasaray		**Bogazici**		**Bahçesehir**		**Yeditepe**		**Kirikkale**	
	Type of station	**Equipment and devices at station**	**Type of station**	**Equipment and devices at station**	**Type of station**	**Equipment and devices at station**	**Type of station**	**Equipment and devices at station**	**Type of station**	**Equipment and devices at station**
Station 1	ASRS	• Vertical ASRS, table-top mounted (72 storage cells) • SCORBOT-ER 5 plus on 1m linear slidebase • 2 spring-loaded part feeders • Palletizing rack	ASRS	• ASRS36 (36 cells)	ASRS	• ASRS-36×2 (72 cells)	ASRS	• ASRS- (40 cells)	ASRS	• ASRS-36×2 (72 cells)
Station 2	Assembly	• SCORA-ER 14 robot • Ball feeder • Automatic gluing unit • Tool changer for robot • 2 palletizing racks	Assembly	• ER9 with tool changer system • 2 palletizing racks • pneumatic device	FMS CELL	• SCORBOT-ER9 on linear slidebase • CNC proLIGHT 3000 lathe • CNC proLIGHT 1000 mill • Palletizing rack	Assembly Station	• Mitsubishi RV-2A (6-axis) robot • Assembly peripherals	Assembly	• SCORA-ER 14 robot • 2 palletizing racks • Ball feeder
Station 3	FMS	• SCORBOT-ER 9 robot on linear slidebase • proLIGHT 1000 milling machine • proLIGHT 3000 turning machine	FMS	• ER9 on linear slidebase • simulated machining processes • 2 palletizing racks	Assembly and Quality Control	• SCORA-ER14 • Palletizing racks • XY positioning table • Pneumatic vise • Ball feeder • ViewFlex machine vision • Automatic gluing system	CNC	EMCO CNC Turn 105 lathe	FMS	• SCORBOT-ER 9 robot on linear slidebase • proLIGHT 3000 turning machine • proLIGHT 1000 milling machine
Station 4	Quality Control	• SCORBOT-ER 5plus robot • XY positioning table • Machine vision system • Parts bin for failed parts • Digital caliper	Quality Control	• ER9 on linear slidebase • pneumatic feeder • Vision system • ball feeder • 2 palletizing racks • gluing machine • caliper	N/A		Quality Control	Analogue positional transducer	Quality Control	• SCORBOT-ER 5plus robot • Parts bin for failed parts • Machine vision system Assembly
Conveyor	• Rectangular loop, approx. 10m total length • PLC control unit • 4 station stop units and indicator lights • Pallet tracking system		• Loop conveyor, approx. 7m total length • PLC cabinet • 2 Station stop units • Pallet Tracking system		• Loop conveyor, approximately 10m total length (3440mm × 1400mm) • PLC control cabinet with OMRON CQM1 • 3 station stop units and indicator lights • Pallet tracking system		• Rectangular loop (1m×3m) • PLC control unit		• Rectangular loop, approx. 10 m total length • PLC control unit	
Additional	• Central CIM management station with software		• The system integrates an AGV (automatic guided vehicle) and Central CIM management control software.		• Central CIM management station with OpenCIM software		• COSIMIR software		• Central CIM management station with Open CIM software	

In succession, other descriptions of CIM education and utilization of facilities are followed, such as Maraghy [14] which presents McMaster University, Canada as an example. The impact of university and industry interaction through research and development projects on CIM and manufacturing education is also discussed. Kwong, Hiranyavasit and Fok [13] discussed the inclusion of a manufacturing information system in production and Operations Management, and they argue that this inclusion substantially improved the teaching of integrated manufacturing.

Koves [11] reviewed industry-government-university cooperation in CIM education in the USA. In his work, he gives examples of how funding from institutions such as the National Science Foundation initiate joint action to establish teaching and training centres. They claim that the result was an ever-increasing availability of CIM professionals. R. Shultz-Wild [23] investigates the CIM status in a German capital goods industry and asserts that concepts of technology, the system of education and vocational training have important influences in determining the direction of further development. Another use of CIM cell is discussed by Ram, Park and Edoka [21] in School of Engineering at North Carolina A&T State University. To be more effective, they propose an interdisciplinary laboratory. Mullins, Shainpoor, Jamshidi, Kassicieh and Starr [18] describe the CIM program and laboratory in University of New Mexico USA established through IBM's CIM in Higher Education Alliance. They have set up instructional programmes at the undergraduate and graduate level in both the Mechanical Engineering and Electrical and Computer Engineering Departments and claim that many Ph.D. and Master's students had used these facilities. They had also established a master's level program between College of Engineering and School of Management by combining manufacturing and total quality management. They also discussed some approaches and future plans. Another description of lab usage is by Shiue, Beard, Santi and Beaini [24] who are at Christian Brothers University, Tennessee USA. In one of the recent studies, Kovacic, Bogdan, Smolic-Rocak and Birgmajer [10] describe ways of using program tools and virtual reality for design and simulation of flexible manufacturing systems for the purpose of teaching undergraduate course of FMS in University of Zagreb, Croatia. Meanwhile, Mehrabi [16] presented ideas for the design of CIM courses and labs currently under development in the College of Engineering and Science at the University of Detroit, USA to support modularity, integrability, customization and open architecture as key features. Similarly, Hung and Leon [6] presented the current approach in manufacturing education and research at Texas A&M University, USA in response to new trends of manufacturing industry. Last but not least, in two separate studies [26–27], the authors reported the CIM efforts conducted in Yeditepe University, Turkey by describing a prototype design and manufacturing project and assessing CIM in systems engineering education, respectively.

Likewise, several studies can be reported on CIM installation and usage. A comprehensive survey conducted recently by Rai, Shankar and Suhaib [20]. Kunnathur and Sundararghavan [12] discussed issues on installation of CIM based on plant visits and extensive interviews as part of a field study. Kimble and Prabhu [9] surveyed CIM usage in manufacturing industry in England. They described the views of senior executives about what problems they have encountered about implementation of CIM and how CIM impacted working practices. Chen and Adam [3] analysed the issues related to computer-integrated-manufacturing and found that the investment led to reduced labour cost, increased output, decreased manufacturing cost, increased flexibility and reduced production lead time. They also reported that there was a moderate relationship between investment and decreased work-in-process inventory and improved quality. Marri, Gunasekaran and Grieve [15] studied performance measurements for the implementation of CIM with the help of an empirical study in British SMEs.

And lastly, several works can be reported on research based on studies in CIM educational labs. For example, Sterna [28] studied late work minimization on a production environment of a CIM system located at the Poznan University of Technology, Poland.

3. REVIEW OF CIM LABS IN TURKEY

Educational CIM cells are used to mimic the real production cycle and enable control and analysis of various aspects of the cycle, from planning through production. They imitate actual manufacturing systems, and aim to train students to operate and gain skills on CIM. By working with a complete CIM system, students can comprehend the functioning of the entire system and interactions within the components. Students can also get hands-on experience with a particular aspect of a CIM system such as controlling robots, Computerized Numerical Control(CNC) machines, etc.

In this section, educational CIM labs are reviewed. Technical trips are conducted to some institutes (such as Galatasaray, Bahcesehir, Bogazici University of Turkey), and web sites of some others (e.g. Yeditepe University) are questioned. The setting of Kirikkale University is also included which will be reviewed in detail in subsequent sections.

CIM lab of Galatasaray University established in 2001 is the first CIM lab in Turkey. Table 1 describes the equipment available in that lab. In Bogazici University, the CIM system, named as Flexible Automation and Intelligent Manufacturing System (BUFAIM) lab, was founded in 2004. The main purpose of the lab is to research the control and integration of modern manufacturing techniques.

The CIM lab in Kirikkale University was established in 2006 by the support of Turkish State Planning Organization (Devlet Planlama Teskilati-DPT). The aim is to research flexible manufacturing models to be used in SMEs by advanced production technologies. The available equipment in this lab is also listed in Table 1.

Like other installations, Kirikkale lab has all the required utilities of a CIM such as a milling machine, turning machine, Automatic Storage and Retrieval System(ASRS), quality control, assembly, etc. Nonetheless, the utilization of the lab and the lecture outline differ from other universities. Firstly, the lab equipment is open to all students and they have hands-on experience using the machines. Interested students may also use the equipment for further projects. Many innovative practices have been experienced as a result of such policy during the short period of establishment. Secondly, the course lecture is not limited to current settings. Students improve their ability by designing and integrating an imaginary system with the same concepts of real complex production systems. In these practices students are the administrator, designer, manager, operator, product supplier and consumer of their factory. They experience—almost for real—the advantages and difficulties of advanced manufacturing systems and the consequences of their decisions. The main aim of the course is the extensive utilization of the lab and CIM concepts.

4. CIM CURRICULUM IN KIRIKKALE UNIVERSITY

The CIM lab in Kirikkale is used in the undergraduate level course of Computer Integrated Manufacturing and Control and in the graduate level course of Flexible Manufacturing Systems Modelling. The undergraduate course is elective in senior year and opened in both Fall and Spring semesters to all students while keeping the classroom size convenient. Both courses are in Turkish due to university policy. Several course outlines are presented for introducing and describing CIM in engineering schools today at various levels of sophistication. Depending on the varying degrees of investment in laboratories, course development efforts and commitment of faculty and professional development, are pursued continuously.

4.1 Lecture outline

In the above CIM courses, students practice in an automation environment and learn several modules from CAD to CAM using laboratory equipments. In Fig. 1, the usage and a lecture outline is described which is designed as a functional model. This kind of model provides a means for consistently modelling the functions (activities, actions, processes, operations) required by the lecture, and the functional relationships and data (information or objects) that support the integration of those functions.

In the function modelling approach, instructional processes and interrelated elements are defined. A similar approach is applied to mobile wireless class [4] and software engineering [8]. The standardized function modelling is called IDEF0 and input, control, output and mechanism are represented by horizontal and vertical arrows. Further information about IDEF0 can be found in [6].

By this way, the students gain knowledge of system software such as milling, turning, robot and quality control, learn to manage and control the equipment. Moreover, they design their own parts and carry out the manufacturing personally.

In successive modules, students sketch their own CIM factory based on the selection of parts to produce. They model and simulate the factory and collect information about the process. Using this information, they try to increase system performance and carry out optimization approaches. A schematic view of the 14 week course schedule is described in Table 2 and the blocks of the lecture are detailed below.

4.2 Lecture Modules

Introduction

The first seminar will be an introduction to the overall course, including the topics. The concept of automation is explained. The advantages and disadvantages of CIM are discussed. A brief description of the installed system is given and a demonstration is carried out.

Module 1: Part Production

In this module, students become familiar with CNC machining. First, students learn universal NC machining code called G-code. This code is also used in industrial size machines. Students are then introduced to computer aided design and manufacturing programs. Although general

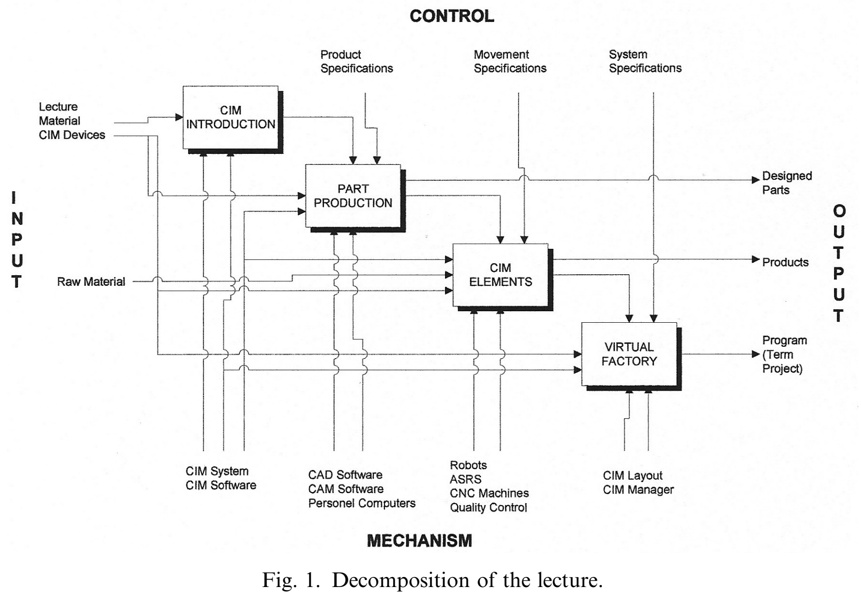

Fig. 1. Decomposition of the lecture.

Table 2. CIM Lecture outline in Kirikkale University

Session	Topics
Introduction and Overview	
1	Lecture and Discussion: Course Importance, Topics
Module 1: Part Production	
2	CNC Machining Basics, G-code introduction
3	Computer Aided Design (Auto CAD and Spectra CAD Engraver Software)
4	Computer Aided Manufacturing (Spectra Light Milling and Turning Software)
Module 2: CIM Elements	
5	Automatic Storage and Retrieval System (AS/RS), Material Handling and Robots
6	CNC Turning and CNC Milling
7	Assembly, Quality Control by Image Processing
Module 3: Virtual Factory	
8	Layout Design
9	Layout Implementation
10	Production Planning
11	Storage setup, Process and Machine Definition
12	Part Definition, producing parts
13	Viewing Production Details, Tracking Integrated Production
14	Improving System Performance, Timing and Optimization

programs can be used in designing a part, such as AutoCAD, a simple CAD program such as Spectra CAD Engraver is explained. A screenshot of the program is given in Figs 3–4. CAM programs for milling and turning are explained afterwards and used on the drawings done in CAD.

Module 2: CIM Elements

In this module, building blocks of a CIM cell are described. These components are necessary for production processes and can be named as robots, storage, machines, quality control and material handling devices. The CIM lab at the Kirikkale has all the above components. Their functions, control and interactions are explained in detail. Students individually are given the chance for hands-on control of the components. They also can produce their own designed parts prepared in a previous module. These activities can be summarized as follows.

Robots: CIM systems are fully automated, and robotic arms are critical components in these automated systems. The tasks they perform include the picking and placing of parts in/from machines, removal of parts from storage, assembling of parts and handling of parts for quality control. Kirikkale CIM has three robots: one for CNC machining stations, one for quality control and one for storage (Figs 2 and 5a). Students are first introduced to some of the robot types and robot tasks used in CIM. Then the control of robots is described. Subsequently, programming of robots for a series of motions is explained.

Storage: A storage station is used to store raw materials prior to production, as well as finished products following the production process. Such stations are fully automatic and controlled by robotic arms, and hence, usually called as Automatic Storage and Retrieval Systems(ASRS). Storage cells in the ASRS contain templates, either empty or containing parts. A view of the ASRS in Kirikkale CIM is given in Figure 5a. Students learn how to prepare storage places by means of indexing of places. They learn the usage and control of raw material, work-in-process and finished products. Robot control is similar to previous one, and the students exercise the use of robots, likewise.

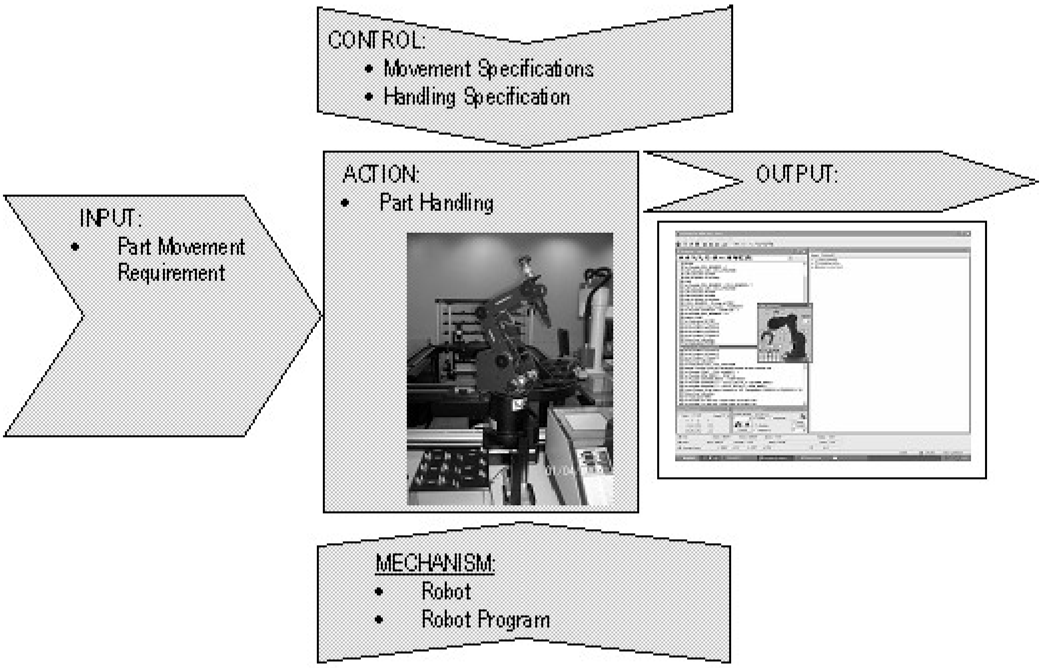

Fig. 2. Robot for CNC machining stations and control program.

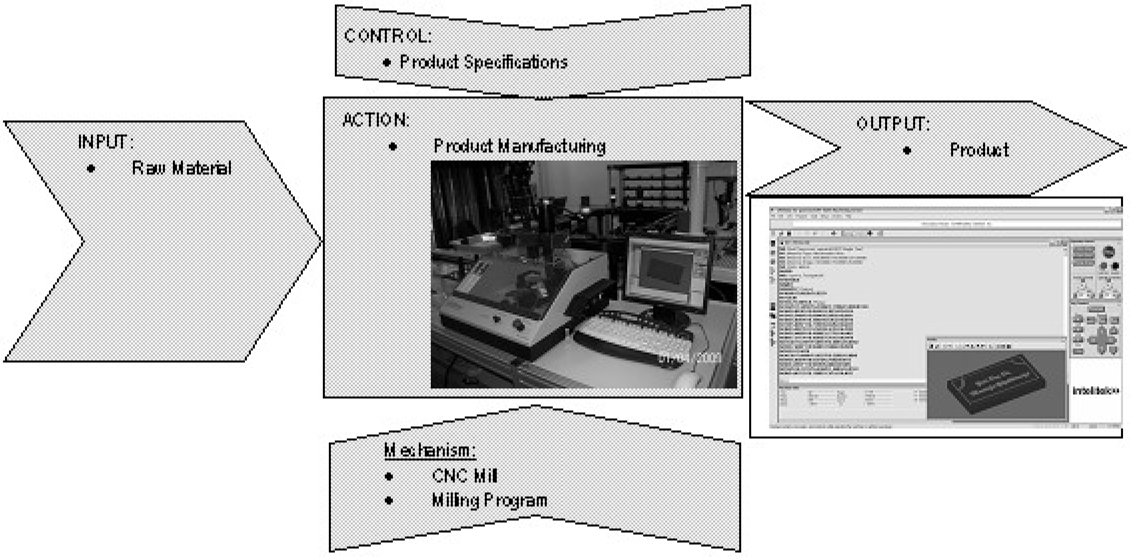

Fig. 3. CNC milling machine and its control program

Machines: Machines are CNC production devices, such as lathe, turning, drilling and laser engravers. Such machines require that parts be inserted or placed into them, usually by a robotic arm. The inserted parts are predefined in size and nature. The machine is programmed in advance to process a particular part, ensuring precise and exact part production. Kirikkale CIM has CNC milling and turning machines. Students first learn to setup and handle these machines. Subsequently, they simulate a part production, and observe how tools of machines behave based on aspects of the part. Lastly, they watch over a part production on an experimental stock made of wax. They are given homework to design their own parts and are asked to produce them in a later scheduled time. Students can keep their parts as souvenir.

Quality Control (QC): This group of equipment includes measuring devices, such as optical systems, laser scan meters and (Coordinate Measuring Machines) CMMs. The purpose of these devices is to determine whether a product meets the quality control specifications defined prior to the production process. In Kirikkale CIM, QC components include high precision measuring tools by image processing. A camera records an assembled part, and accepts or rejects part according to the image. Students first observe this process, then learn to handle the procedure.

Material handling devices: CIM components are located in multiple production stations that are physically distant from one another. This requires a system that moves parts from one robotic station to another. Material handling devices are used for this purpose. In Kirikkale University CIM, a

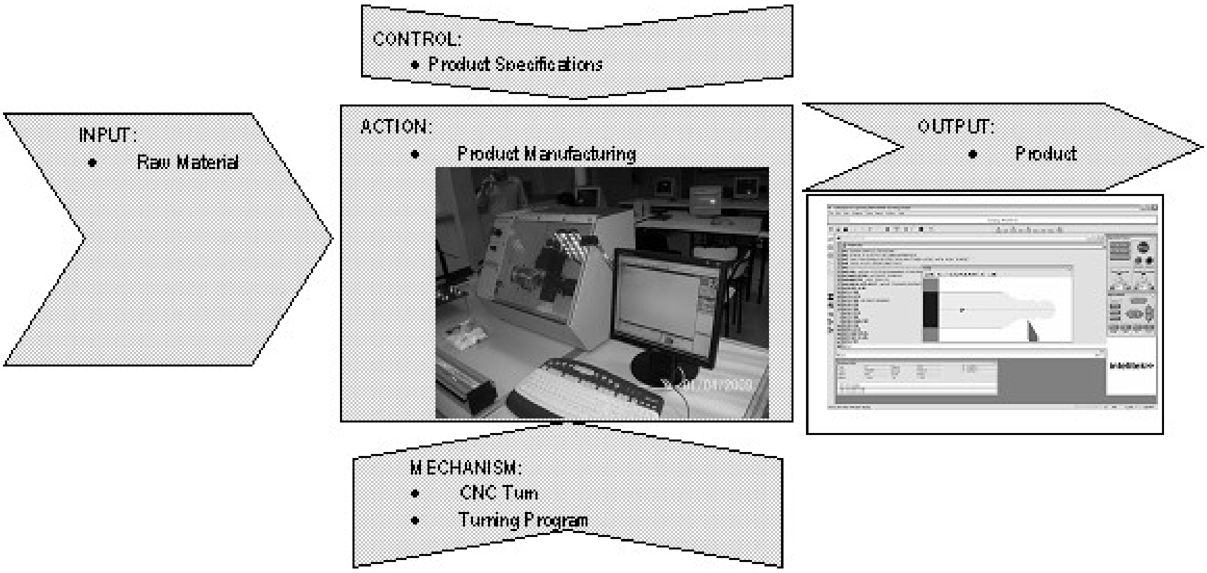

Fig. 4. CNC turning machine and its control program.

(a) (b)

Fig. 5. Storage and material handling devices of CIM. (a) Automatic Storage and Retrieval System (AS/RS). (b) Closed loop conveyor.

closed loop conveyor with stop stations controlled by PLC is present (Fig. 5b). The stop stations are controlled by the PLC and enable the robot to pick a part from the conveyor and place the part on it. Students track part movements, learn interaction of the conveyor with stations. They also learn underlying principles how stop stations work and separate parts based on palette.

System Manager: The CIM system has a manager program which controls the entire system. Every other station and its controlling programs interact with this program and functions according to the predefined sequence. The system manager monitors the system real-time.

Module 3: Virtual Factory

In this module students learn to design and operate their own CIM factory independent from the installed system. The goal is to simulate a hypothetical factory and improve the system performance. For this purpose, the procedures for layout design, implementation, storage setup, product and machine definition and producing new parts are taught. Students also get familiar with tracking production and improving system performance

4.3 Student assignments and projects

Students are assigned homework and a number of term projects. In the first week, they are encouraged to acquire general information about CIM and its literature. In a part production module, students are required to design their own parts. They are told that their grade would be based on the complexity of part shape and encouraged to use complex manufacturing techniques. In the third part which is the CIM elements module, students are required to manufacture their design. For safety, students are monitored, but expected to operate the robots and machines by themselves. In the virtual factory module of 4, a term project is assigned.

4.4 Impact on industrial engineering curriculum

In this section, we evaluate the contribution of

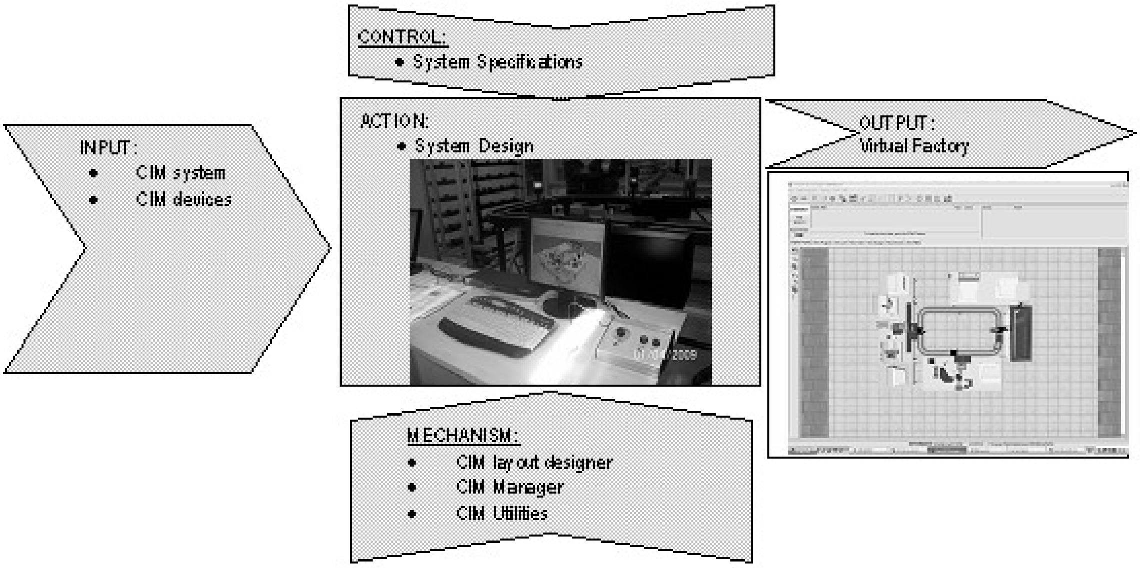

Fig. 6. Virtual factory.

Table 3. CIM Lecture outline in Kirikkale University

Course	**Term**	**Related CIM Lecture Module**	**Contribution**
Work Study	III	Module 2: CIM Elements and Module 3: Virtual Factory	Students are able to apply their skills in time study and use of standard data.
Intro to Electronics	IV	Module 2: CIM Elements	Students understand the basic electrical elements. They learn the application of electrical circuits and computer interaction.
Operations Research-I and II	V	Module 3: Virtual Factory	Students gain the ability to model real life problems as a mathematical model, to find optimal solutions and perform scenario/sensitivity analyses.
Production Planning I and II	V	Module 3: Virtual Factory	Students learn the importance of planning, methods and definition of demand forecasting and inventory management. They learn different inventory management methodologies, master production planning and its methodologies.
Management of Information Systems	V	Module 2: CIM Elements	Students learn the fundamentals required for the design of integrated information systems. They gain knowledge on computer hardware including communication networks, workstations/personal computers and automatic identification equipment.
Simulation	V	Module 3: Virtual Factory	Students can take a closer look at system's behaviors and comparison of alternative system designs. They investigate the use of simulation for optimization purposes.
Manufacturing Processes	VI	Module 1: Part Production	Students get familiar with the advantages and limitations of manufacturing technologies. They recognize the tool and machines used in manufacturing and gain the capability of proper tool and machines selection in applications.
Quality Control	VI	Module 2: CIM Elements	Students get familiar with the concept of quality and its place and importance in production systems. They learn the state-of-art tools for quality engineering.
Facility Layout and Planning	VI	Module 2: CIM Elements and Module 3: Virtual Factory	Students gain the ability to set evaluation criteria for a facility, and required principles of operations for building a new facility. They can calculate machine and equipment requirements and placement techniques of equipment.
Production Systems	VII	Module 3: Virtual Factory	Students understand the fundamental topics of manufacturing systems, classifications and analysis of automated manufacturing systems. They gain knowledge of traditional and non-traditional processes, cellular design, flexible flow lines, lead time analysis, and work flow leveling and balancing.

the described CIM lecture to the Industrial Engineering curriculum. Although, the courses from Kirikkale University are taken as a reference, they are quite general in IE curriculums worldwide.

5. ISSUES ARISING FROM USING CIM

CIM systems are highly complex and expensive structures. Careful and extensive planning is therefore needed before installation of the system. The issues on the installation of a system have been subjects of several studies such as Kunnathur and Sundararaghavan [12] and Raj, Shankar and Suhaib [20]. These topics can be summarized as loading of parts in FMS, scheduling techniques, material handling and flexibility and its measurement, machine tools, operation, control and maintenance techniques, human element and culture. The researchers also recommend the following actions for a successful installation:

- Obtain continuous feedback from functional units;
- Information system department should participate in analysis of software capabilities and limitations;
- Develop a master plan and monitor it by performance criteria;
- Consider enhancements for a long-term automation projects;
- Integrate automation into the portfolio of manufacturing facilities.

At the same time, researchers suggest these actions to avoid during an installation:

- Evaluating CIM projects as a one-time occurrences;
- Bundling software and machinery acquisition decisions;

- Acquiring CIM solely for high volume high precision operations;
- Contracting for turnkey installation;
- Creating island of automation.

These issues and actions are very important and can be generalized for all CIM installations. However, educational CIM settings require different treatment due to their purpose and objective. Based on our experience and interview with other supervisors of CIM installations in Turkey, the following issues are identified and discussed, in usage of CIM labs:

5.1 General

Once installed, the CIM system is a small-scale factory. The system allows for implementation and demonstration of various devices and components used in a modern manufacturing environment. Each device can be individually programmed/operated, and the entire system is integrated through networks. Moreover, advanced manufacturing planning methodologies can be adopted and their consequences can be observed. Therefore, students develop their ability to design and integrate complex manufacturing systems and can experience various integration issues in a modern plant.

In addition to the physical structure, virtual simulation of an imaginary system with the same concepts of a real one can be carried out. In these experimental setups, students can experience and understand fundamentals of assembly systems, system layouts/configurations and their impact on throughput, quality, and reliability; material transport systems; part delivery systems at workstations; single and multi-station assembly machines/stations; design for automated assembly; and automation of assembly systems.

5.2 Undergraduates

Most of Turkey's installed CIM labs are in Industrial Engineering departments, hence the supervisors are academicians from this discipline. Consequently, the courses taught and ongoing researches are viewed in that direction. However, by nature, CIM installations are interdisciplinary. As well as subjects that engage industrial engineers, in CIM systems, there are computer software and hardware which could be interesting for computer engineers, electronic communication and control components which could be attractive for electrical-electronic engineers, actual replica of industrial machining and manufacturing which could be appealing to mechanical engineers.

Therefore, CIM labs should be used in collaboration and departments should establish closer relationships with each other, i.e. industrial, mechanical, electrical-electronic and computer engineers to achieve common goals for manufacturing. Some aspects of these groups may even combine to be more efficient. By introducing interdisciplinary learning, students will develop skills for direct interaction and communication with individuals from a variety of fields. Moreover, courses and projects should be encouraged that enable these interdisciplinary experiences. Students will be able to anticipate the need to function in dispersed disciplines, especially using language of engineering to communicate. As a result, graduates will be able to function on, and contribute meaningfully to the workforce in product manufacturing, problem solving, or other efforts.

It is also suggested that a new programme of manufacturing engineering could be formed to focus solely on computer integrated manufacturing issues. In this minor, it is suggested that the modern concepts of computer integrated manufacturing and productivity programmes should be pervasive in the curriculum. Students should understand the basic tools and methods of systems engineering and integration. They should understand CAD, CAM, machining, project management and MRP systems. They should especially understand the life-cycle design constraints related to manufacturability, reliability, maintainability, etc. Students must understand computer integrated material processing methods, especially processes that go beyond the traditional metal processing. It is also suggested that students should be prepared for process planning regardless of the type of material used. It is recommended that the curriculum has a unifying theme that ties disciplines together. A virtual factory, a product development experience, or other major project may serve as an appropriate tool.

5.3 Graduate studies and research

CIM is probably the most challenging concept which has faced manufacturing. Several of the issues already discussed can be amended for graduate research. In addition, since CIM requires the latest and most advanced computer technology, software and hardware engineering skills, it involves new manufacturing control methodologies. In principle as well as in practice, CIM can reach into every relevant aspect of a manufacturing business. Manufacturing control, business and financial strategy and supply and distribution are as important as automation of manufacturing. These broad topics open new challenging research areas.

CIM laboratories are a good home for studies established on scientific methodologies and aimed at creating new knowledge, scientific interpretation or solution of technological problems. These innovative technologies will increase the competitive aspects of emerging countries such as Turkey. To create new knowledge, scientists from different disciplines should collaborate on developing novel techniques. It is noteworthy to mention that research is being conducted by utilizing The Kirikkale CIM with the title of 'Queueing Network Models of Flexible Manufacturing System' which is supported by The Scientific and Technological Council of Turkey (TUBITAK).

5.4 Technical high schools and industry relations

CIM education and concepts could be broadened to beyond university usage. Opportunities exist for extending manufacturing engineering education to technical high school students and industrial operators and managers. Maximizing effective use of the limited resources of emerging countries such as Turkey requires this kind of utilization. First, individual operation and encoding of a device in a CIM cell can be instructed to the workforce who actually use/will use it. Second, an appropriate manufacturing cell can be developed and applied to institutions to demonstrate and educate on manufacturing concepts. These training programmes will serve as a means to ending industry's need for skilled employees. It will also cut the learning period of machinist to a minimum. By proper design of the curriculum, the lectures and seminars can be carried out by Distance Learning systems to students/trainees who need them. And lastly, feedback from industry practitioners and leaders would shape the next generation manufacturing systems.

6. SUMMARY AND CONCLUSIONS

Computer Integrated Manufacturing is a manufacturing system that consists of numerically controlled machines connected through automated handling devices which are controlled by a central network computer. Educational CIM labs are replications of real production systems which are used to train students to operate, control and analyse various aspects from planning through production. In this study, educational CIM cells are reviewed in Turkish engineering schools. Further, a CIM curriculum which aims to utilize the lab equipment and CIM concepts and is currently used in Kirikkale University is described in detail. Lecture modules of part production, CIM elements and virtual factory are explained, and required tools and expected contributions to students are depicted. Lastly, issues on the usage of CIM are discussed. Points are made regarding installation, undergraduate, graduate studies and research, technical high schools and industry relations.

The main contribution of the study is to pave a way for educational institutions intending to establish a CIM system. Using this study, they will be able to compare existing systems and plan accordingly. They will also purchase the equipment appropriate to their purposes and spend their resources wisely. We have also described current usage and discussed alternative ways to improve utilization of the system. Existing and future CIM lab owners will benefit from this description and discussion to progress and revise their usage.

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REFERENCES

1. S. Alptekin, C. Benjamin and Y. Omurtag, A Suggested Model Program for CIM Education, *Proceedings of Rensselaer's Second International Conference on 21–23 May 1990*, 1990, pp. 86–9.
2. R. G. Askin and C. R. Standridge, *Modelling Analysis Of Manufacturing Systems, Wiley*, USA. 1993.
3. F. F. Chen and Jr E. E. Adam, The Impact Of Flexible Manufacturing Systems on Productivity and Quality, *IEEE Transactions On Engineering Management*, **38**(1), 1991, pp. 33–45.
4. R. Chompu-inwai and T.L. Doolen, IDEF functional modeling for Instructional Processes in Mobile Wireless Technology Classrooms, *Proceedings of 34th International Conference on Comuters & Industrial Engineering*, 2006, pp. 61–66.
5. J. R. Crookal, Education for CIM, *CIRP Annals—Manufacturing Technology*, **36**(2), 1987, pp. 479–494.
6. W. N. P. Hung and V. J. Leon, Manufacturing Education and Research at Texas A&M University: Responding to Global Trends, *Journal of Manufacturing Systems*, **24**(3), 2005, pp. 153–161.
7. Integration Definition for Function Modelling (IDEF0), Federal Information Processing Standards publication 183, Computer Systems Laboratory, *National Institute of Standards and Technology*, 1993.
8. R. Kawabata and K. Itoh, Diagrammatic Education for Software Engineering, *Journal of Integrated Design and Process Science*, **10**(1), 2006, pp. 79–92.
9. C. Kimble and V. B. Prabhu, CIM and Manufacturing Industry in The North East Of England: A Survey Of Some Current Issues. *CIM and Manufacturing Industry in the North East of England: a Survey of some Current Issues in Ergonomics of Advanced Manufacturing Systems.* Eds H. R. Parsaei & W. Karwowski. Elsevier publications, 1988, pp. 133–140.
10. Z. Kovacic, S. Bogdan, N.Smolic-Rocak and B. Birgmajer, Teaching Flexible Manufacturing Systems by Using Design and Simulation Program Tools, *Proc. Of EUROCON 2003*, 2003, pp. 47–51.
11. G. Koves, Industry-Government-University Cooperation to Establish CIM Education in the USA, *Computers in Industry*, **14**(1–3), 1990, pp. 193–196.
12. A. S. Kunnathur and P. S. Sundararaghavan, Issues In FMS Installation: A Field Study And Analysis, *IEEE Transactions On Engineering Management*, **39**(4), 1992, pp. 370–377.
13. K. K. Kwong, C. Hiranyavasit and W. M. Fok, An Effective Approach to Enhance Production and Operations Management Education in Colleges of Business, *Education and Computing*, **5**(3), 1989, pp. 181–188.

14. H. A. El Maraghy, Computer Integrated Manufacturing Education and Research, *Journal of Manufacturing Systems*, **6**(4), 1987, pp. 329–337.
15. H. B. Marri, A. Gunasekaran and R. J. Grieve, Performance Measurements in the Implementation of CIM in Small and Medium Enterprises: An Emprical Analysis, *Int. J. Prod. Res.*, **38**(17), 2000, pp. 4403–4411.
16. M. G. Mehrabi, Lab System Design Design in Support of Manufacturing Engineering Curricula, *Journal of Manufacturing Systems*, **24**(3), 2005, pp. 251–255.
17. J. G. Monks, *Operations Management: Theory and Problems*, McGraw-Hill Inc, USA, 1987.
18. J. H. Mullins, M. Shainpoor, M. Jamshidi, S. K. Kassicieh and Starr G. P., Robotics and Manufacturing Education and Research— the New Mexico initiatives, *Robotics and Computer-Integrated Manufacturing*, **9**(1), 1992, pp. 15–25.
19. J. Peklenik, Report on CIRP Int. Seminar on Education and Training for Manufacturing Systems and Computer Integrated Manufacturing, J*ournal of Manufacturing Systems*, **12**(1), 1993, pp. 131–36.
20. T. Raj, R. Shankar and M. Suhaib, A Review of Some Issues and Identification of Some Barriers in the Implementation of FMS, *International Journal of Flexible Manufacturing Systems*, **19**, 2007, pp. 1–40.
21. B. Ram, E. Park and S. Edoka, An Interdisciplinary Laboratory for Manufacturing Education, *Computers & Industrial Engineering*, **25**(1–4), 1993, pp. 61–64.
22. T. Sata, F. Kimura, University Education for Fundamentals of CIM, *Journal of Manufacturing Systems*, **5**(3), 1986, pp. 133–143.
23. R. Schultz-Wild, CIM and future factory structures in Germany, *Futures*, **23**(10), 1991, pp. 1032–1046.
24. Y. Shiue, B. B. Beard, M.L. Santi and J. E. Beaini, Integrate Laboratory for Manufacturing Education, *International Journal of Engineering Education*, **15**(1), 1999, pp. 51–57.
25. D. Sipper and L. R. Bulfin, *Production Planning, Control and Integration*, McGraw-Hill Inc, USA. 1997.
26. S. Sisbot, M. Tunc and Ü. Çamdali, Implementation and Assessment of Computer Integrated Manu-facturing in Systems Engineering Education, *Computer Applied Engineering Education*, accepted paper, 2009.
27. S. Sisbot, M. Tunc, Ü. Çamdali and Y. Turkkan, Yeditepe University Computer Integrated Manufacturing Studies, *Computer Applied Engineering Education*, **17**, 2009, pp. 1–12.
28. M. Sterna, Late Work Minimization in a Small Flexible Manufacturing System, *Computers & Industrial Engineering*, **52**, 2007, pp. 210–228.

Mustafa Yuzukirmizi is an assistant professor at the Department of Industrial Engineering and co-chair of Graduate School of Science in Kirikkale University, Turkey. He received his Ph.D. from University of Massachusetts-Amherst, MA USA, MS from Northeastern University, Boston, MA, USA and B.S. from Istanbul Technical University, Turkey. His research interests includes computer integrated manufacturing systems, queueing theory, simulation of production systems and engineering education. Since 2007, he has been the university coordinator of Industry-Academia research alliance. He carried out sponsored research for The Scientific and Technological Research Council of Turkey (TUBITAK) and is an author and coauthor of numerous papers published in journals and presented at national and international conferences.