THE USE OF SOFTWARE TOOLS FOR ChE EDUCATION
Students' Evaluations

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Over the last two decades, we have witnessed a rapid decline in the computer price/performance ratio and the development of fast, reliable, and user-friendly computer packages. These developments have brought computers within the reach of organizations and people who were once deterred by cost or by complex mathematics and programming expertise. The ease of use and enhanced capabilities of general-purpose software such as Mathcad or Matlab have made it possible for engineers with limited or no formal training in programming to solve relatively complex problems.

The available computing tools have led to large changes in the industrial world. In contrast, the typical engineering educator has been slow to incorporate computer-based concepts in the curriculum and training methods. This situation has been attributed to a number of factors, including the lack of computer literacy/inclination among certain staff and the way popular textbooks are written.[1,2]

The positive impact of information technology on teaching and learning is no longer questionable.[3-5] Kulik and Kulik[4] reported that most studies found that computer-based instruction—using technology of the eighties—had positive effects on students. In particular, students learned more and faster (the average reduction in instructional time in 23 studies was 32%). The students also developed more positive attitudes and liked classes more when they use computers.

The main objective of this paper is to present our experience with and students' evaluations of three commercial software packages that we at the Department of Chemical Engineering at the University of Bahrain have been using as teaching aids. These packages are the process control training software Control Station <www.control.station.com>, the process flowsheeting package HYSYS <www.hyprotech.com>, and the general-purpose computational package Mathcad <www.mathsoft.com>.

CONTROL STATION

Control Station (CS) is a process dynamics and control training simulator that provides access to several simulated processes.[6,7] The case studies include gravity-drained tanks, a pumped tank, a heat exchanger, a jacketed reactor, a furnace, a multitank process, and a binary distillation column. The software also allows the user to build tailor-made processes and single-loop (or 2 x 2) control structures using a transfer function block-oriented environment. Linear process models and Proportional-Integral-Derivative (PID) controller settings can be developed using the design module of the software package. The available controllers in version 3.0 of CS include the classical PID and its variants, cascade, feedforward, Smith predictor, decoupler, and sampled-data and single-loop Dynamic Matrix Control (DMC).

During the last few semesters, we have used Control Station as a teaching aid in a number of bachelor and diploma courses on process dynamics and control. We use it for both assignments and hands-on workshops. As shown later, the

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feedback from the students on the use of the program was very positive. The program made it easier for them to understand process control material and concepts in a shorter time than traditional lecture-only classes. It also helped the students relate theory to practice.

Two workshop examples of how CS can be used to teach control concepts are shown in Figures 1 and 2. Figure 1 illustrates why the derivative action should not be employed for processes having noisy measurements; the addition of the derivative action to a PI controller leads to a deterioration

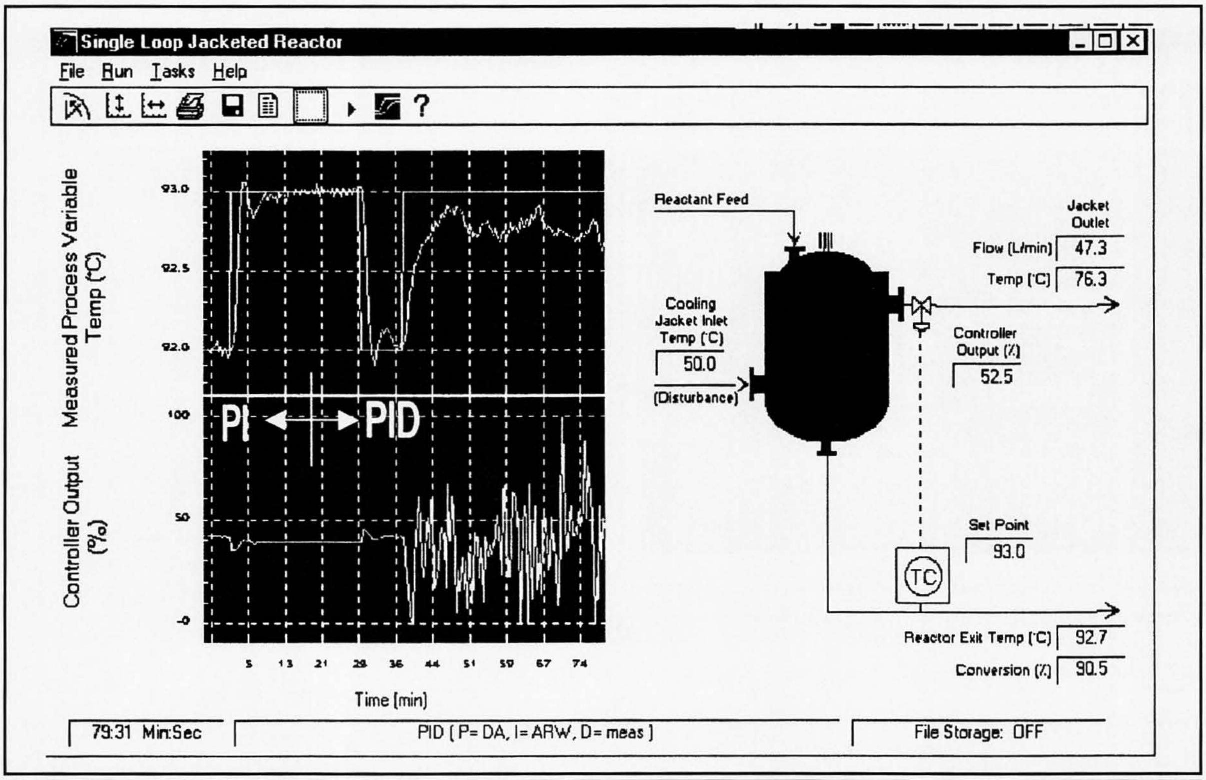

Figure 1. *Impact of noise on derivative action (Control Station).*

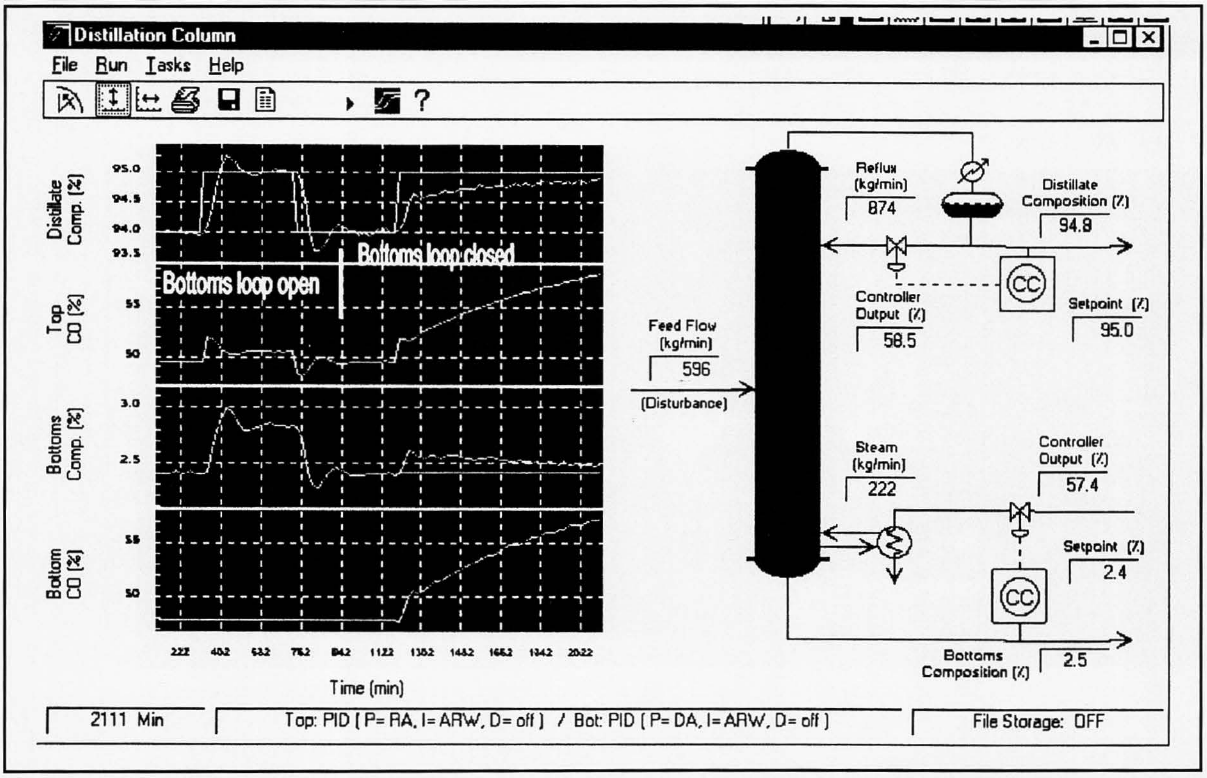

Figure 2. *Effect of interaction on SISO loops (Control Station).*

(not an improvement) of the closed-loop response. Also, the derivative term leads to unacceptable fast movement of the control valve.

The use of CS significantly contributes to teaching advanced control strategies such as feedforward, cascade, and decoupling control to undergraduate students. Figure 2 illustrates the effect of process interaction on the performance of conventional controllers in multi-input/multi-output processes. The distillate composition controller results in good closed-loop performance when the bottoms composition con-

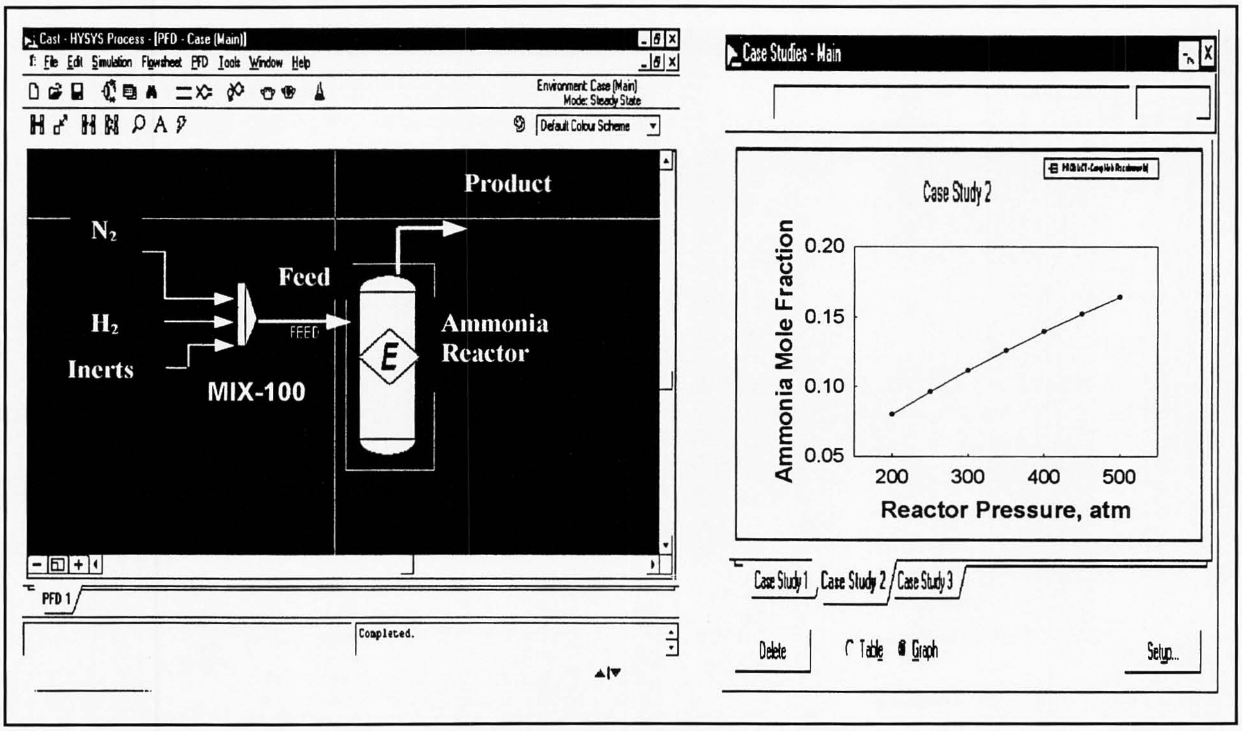

Figure 3. *Simulation of an ammonia reactor (HYSYS).*

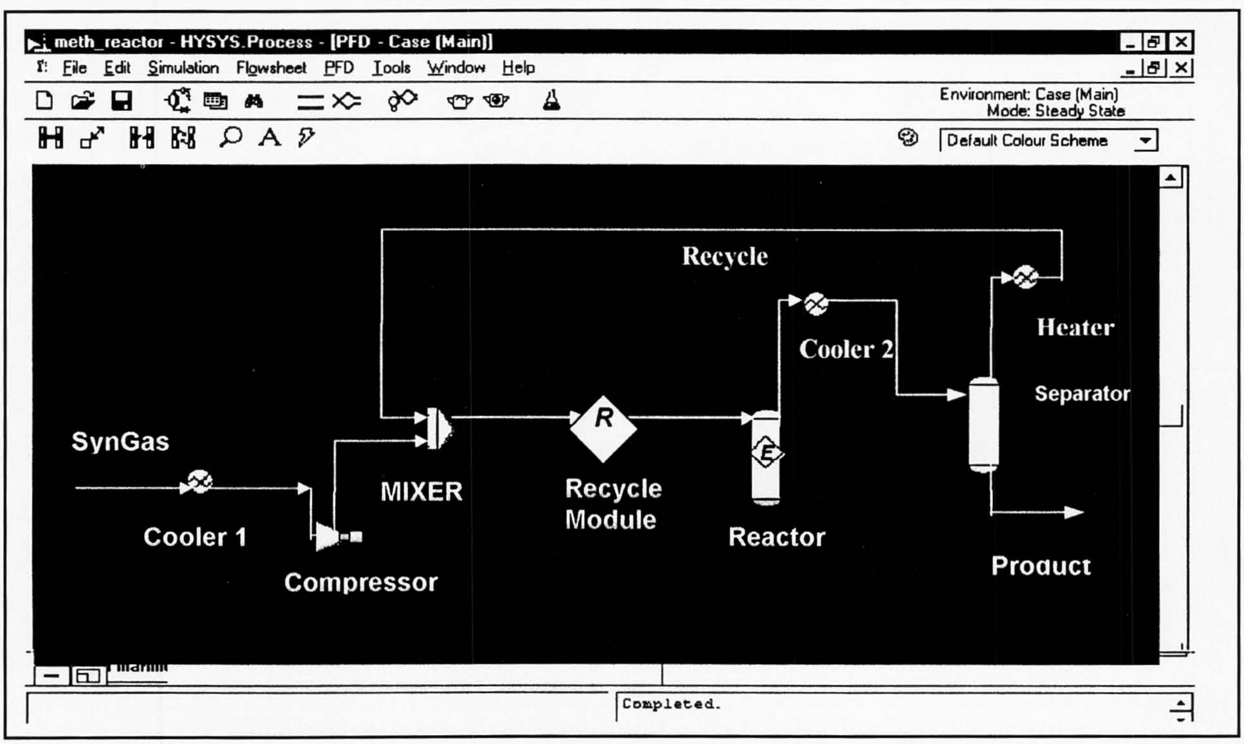

Figure 4. *Methanol synthesis loop (HYSYS).*

troller is on manual mode. Closing this latter loop leads to a deterioration of the performance of the first loop due to the "fight" or interaction between the two controllers. The students are usually asked to check the loops' interaction by calculating the relative gain array[8] and to design and test a decoupler for the distillation column.

HYSYS

HYSYS is a modular commercial process flowsheeting program that is widely used by universities and industry (particularly hydrocarbon-related companies). It is capable of doing material and energy balances for static and dynamic conditions and is a very powerful tool for process simulation. It has built-in routines to solve many specialized unit operations. One of the important features of HYSYS is the availability of an "Oil Manager" option dedicated to support refinery simulations. A comprehensive library of thermodynamic property packages is supplied with HYSYS to enable the user to design and solve many types of problems. At the Chemical Engineering Department of the University of Bahrain, HYSYS is used as an effective teaching tool in a number of courses including process analysis (material and energy balances), plant design, and the senior projects.

TABLE 1
Students' Evaluation Forms

1. Justification for the use of program in the course *(1 = unjustified; 5 = absolutely justified)*
2. Contribution to study of the subject by program use *(1 = irrelevant; 5 = very effective)*
3. Ease of achieving the goal *(1 = difficult; 5 = easy)*
4. Clarity in the means used to convey knowledge *(1 = confusing; 5 = absolutely clear)*
5. Relationship between the complexity of the concept given and the resources supplied *(1 = inadequate; 5 = absolutely adequate)*
6. Number of resources (information) simultaneously presented on screen *(1 = excessive; 5 = balanced)*
7. Computer skills required *(1 = excessive; 5 = null)*
8. General quality of presentation *(1 = poor; 5 = excellent)*
9. Effectiveness of the resources used: graphics, tables, and texts *(1 = ineffective; 5 = very effective)*
10. Ease of operation *(1 = complex; 5 = very easy)*
11. Documentation for user *(1 = deficient, 5 = excellent)*
12. Clarity of the goal *(1 = confusing, 5 = perfectly defined)*
13. Correspondence between program and knowledge conveyed in class *(1 = absolute disconnection; 5 = highly related)*
14. Amount of specific knowledge required about subject for program use *(1 = excessive; 5 = reasonable)*
15. Degree of interaction between user and program *(1 = passive schemes; 5 = very interactive)*
16. Time needed for program execution *(1 = excessive; 5 = suitable)*

Comment on the reasons for which you felt attracted to or bored by the program.

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In the process analysis course, students follow a systematic approach in which they effectively analyze the systems and develop comprehensive degree-of-freedom tables to determine if a problem is correctly specified and also the order of solving the various units. The basic concepts used in modular simulation packages are thoroughly discussed. Among the problems associated with modular solution is the presence of recycle streams, which necessitate the iterative tear stream solution. Determining the number of tear streams, their positions, the convergence techniques, and the order or sequences of their converging are basic issues that we clarify.

Figures 3 and 4 show flow diagrams of simple HYSYS case studies that the students were requested to develop. In Figure 3, the effect of operating parameters such as temperature, pressure, and composition of inerts on the production rate are evaluated for an equilibrium-type ammonia reactor (parametric analysis). The variation of ammonia output composition with the operating pressure is shown in Figure 3. The significance of the recycle loop and the selection of the suitable convergence acceleration method are emphasized by the second case study on a methanol synthesis loop (Figure 4). Solving this problem also gives students insight into the philosophy of the modular flowsheeting programs and the nature of the sequential solution strategy.

MATHCAD

Mathcad is one of the four most popular computational packages used in industry and academia; the other three programs are Matlab, Maple, and Mathematica. Mathcad combines some of the best features of spreadsheets (like MS Excel) and symbolic math programs. It provides a good graphical user interface and can be used to efficiently manipulate large data arrays, to perform symbolic calculations, and to easily construct graphs. One of the useful features of Mathcad that is not found in the aforementioned programs is its ability to perform calculations with units; this is indeed an important feature for engineering students. In a recent survey conducted by the discussion group on Computer Applications in Chemical Engineering <http://www.che-comp.org/>, Mathcad was the preferred computational package for 16.2% of participants. The survey included a large number of known packages, and the only two programs preferred by more people were MS Excel (35.3%) and Matlab (23.4%).

As a general programming package, Mathcad is being used in the Chemical Engineering Department in several courses including process analysis, process modeling and simulation, equipment and plant design and the senior projects.

STUDENTS' EVALUATIONS

To measure the usefulness and effectiveness of the considered software packages, students filled out the evaluation form shown in Table 1 at the end of the course for which the software was used. The sixteen questions were selected from the list of 24 questions proposed by Iglesias, *et al.*[9] Eight questions were dropped based on the recommendations of the authors and the inability of students to clearly understand some of them. Iglesias and co-workers classified the questions in three categories: teaching content and methodology (questions 1-5), software and design features (questions 6-10), and user reaction (questions 11-16).

The first class attempts to test the usefulness of the educational software in terms of subject content and design features, as well as the teaching methodology used in the course. The second category evaluates mainly the user interface (number of resources presented, quality and effectiveness of graphics, tables, animation, etc.) and ease of use of the package. The third class tests the user's reaction to the program by considering aspects such as documentation for user, degree of interaction between user and program, and time needed for program execution. Note that the three categories are not totally independent and distinct. The questionnaire ends by asking students to comment on the reasons they felt attracted to or bored by the program.

The students' evaluations for the three considered packages are shown in Tables 2 to 7. The overall results are presented in Figure 5. Control Station and Mathcad were, respectively, evaluated by the process control and process analysis undergraduate classes. HYSYS was evaluated by stu-

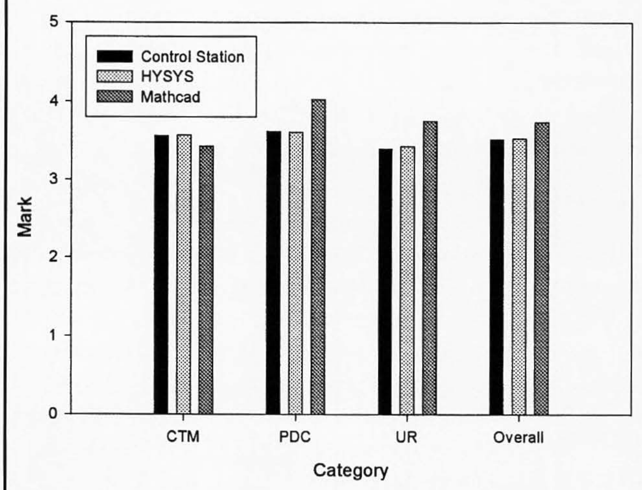

Figure 5. *Overall marks for the three packages. CTM = Content and Teaching Methodology, PCC = Program Design Characteristics, and UR = Users' Reaction.*

TABLE 2
Evaluation Results for Control Station (10 students)

Question	Mean	Standard Deviation
1	4.10	0.99
2	3.70	0.82
3	3.20	1.03
4	3.30	0.95
5	3.50	0.97
6	3.90	0.88
7	3.40	1.07
8	3.50	0.71
9	3.90	0.74
10	3.40	1.17
11	2.90	1.20
12	3.10	0.88
13	3.90	0.99
14	3.00	0.47
15	3.40	0.84
16	4.10	0.99

Comment on the reasons for which you felt attracted to or bored by the program.

TABLE 4
Evaluation Results for HYSYS (21 students)

Question	Mean	Standard Deviation
1	3.59	1.33
2	4.00	1.07
3	3.50	0.91
4	3.41	1.14
5	3.36	1.05
6	3.59	1.18
7	3.59	1.05
8	3.57	1.16
9	4.27	0.83
10	3.05	1.05
11	2.86	1.08
12	4.18	0.80
13	3.82	1.22
14	3.32	1.09
15	3.32	0.99
16	3.09	1.34

TABLE 3
Overall Marks for Control Station

Category	Mean	Standard Deviation
Content and teaching methodology	3.56	0.97
Program design characteristics	3.62	0.92
Users' reaction	3.40	0.99
Overall	3.52	0.96

TABLE 5
Overall Marks for HYSYS

Category	Mean	Standard Deviation
Content and teaching methodology	3.57	1.11
Program design characteristics	3.61	1.11
Users' reaction	3.43	1.17
Overall	3.53	1.12

dents from process systems engineering courses. As the tables and Figure 5 show, the students' evaluations of all three software packages were highly favorable; the overall marks varied within a relatively narrow range (3.52 to 3.74).

For the case of control station, questions 1 and 13 received high marks, indicating a strong correlation between the software and the knowledge conveyed in the class, and also that the use of computer workshops in the course is highly justified. Question 14 received the second lowest mark (3.0). This was expected since chemical engineering students do generally feel that their first process control course includes more material than an average course and that it is rather difficult. This is due to the well-known fact that process control is much different from traditional chemical engineering courses and that it includes a significant number of new theories and terms.

For HYSYS, questions 2, 9, and 12 received the highest marks, indicating that the students found the software resources to be very effective and that the program has significantly contributed to their study of the courses considered. Note that prior to the availability of process flowsheeting packages, the students had to manually carry out lengthy design calculations. The students gave their lower ratings to questions 10 (3.05) and 16 (3.09), *i.e.,* they felt that the program was not very easy to operate and that the time for simulating case studies was too long. The speed of execution is, of course, dependent on the size of the problem at hand. With HYSYS being a commercial flowsheeting package, even simple problems include a significant number of details.

High marks were given to questions related to Mathcad design characteristics; the overall mark is 4.03 (see Table 7). This is not surprising since the package is truly user-friendly and the fact that prior to using Mathcad, the students were programming in FORTRAN. For all three programs, the students evaluated the programs' documentation as above average (see question 11). Although we feel that the material handed out to the students was very good, this issue is currently being addressed by conducting more tutorials on the use of the packages, supplying the students with more copies of shorter versions of the users' guides, and preparing simpler getting-started handouts.

TABLE 6
Evaluation Results for Mathcad (6 students)

Question	Mean	Standard Deviation
1	3.50	1.52
2	3.33	1.51
3	3.33	1.03
4	3.67	1.21
5	3.33	0.82
6	4.50	0.55
7	3.67	0.52
8	4.00	1.10
9	4.00	0.63
10	4.00	1.10
11	3.17	1.17
12	3.50	1.05
13	4.17	1.60
14	4.50	0.84
15	3.67	1.37
16	3.50	1.05

TABLE 7
Overall Marks for Mathcad

Category	Mean	Standard Deviation
Content and teaching methodology	3.43	1.17
Program design characteristics	4.03	0.81
Users' reaction	3.75	1.20
Overall	3.74	1.10

CONCLUDING REMARKS

The computer has become an integral part of engineering education. As the power of both hardware and software continues to rapidly increase, we expect the use of information technology in the classroom/laboratory to grow at a much faster rate in the near future.

The use of multimedia and software packages enhances teaching and learning. In particular, the students learn more and faster, allowing the teacher to cover more material in the time allocated for the course. Of course, the information technology tools have a large number of benefits that are not within the scope of this paper. For example, they are invaluable tools for web-based education and distance learning and training.

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