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Spreadsheet Applications in Engineering Education: A Review*

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In the past few years, spreadsheets have become a popular computational tool and a powerful platform for performing engineering calculations. Simplified program development and debugging, the use of named ranges and labels that enhance readability of formulas and ability to manipulate matrices aided this heightened popularity. The use of macros for looping and other high-level programming needs, and its widespread availability and portability also promoted its acceptability. Yet, a comprehensive literature review on engineering spreadsheet applications appears lacking. This work fills a gap by presenting a scientific literature review of engineering spreadsheet applications. With this work, new entrants into the field would benefit by having insights into researchable areas, thereby speeding up research and effectively utilising research resources.

INTRODUCTION

RESEARCH ON SPREADSHEETS in engineering education in the last two decades has placed great challenges on educators and other stakeholders to apply this computational tool both theoretically and practically towards improving the teaching-learning paradigm. These recent challenges have forced institutions of higher education to adapt spreadsheets for instructional purposes with its enhancement tools as a means to improve the quality of engineering education. The need for high quality, learning-centred education has therefore made the application of spreadsheets important.

Primarily, the literature on spreadsheets in engineering education is wide, encompassing diverse areas and disciplines. The successful application of spreadsheets in engineering education can be cited in on-line instructions and distance-learning programmes. Although numerous papers exist in the literature on spreadsheets, little integration exists across studies. Unfortunately, researchers seem to be in a Tower of Babel where they do not understand what other people, who are doing the work with them, are doing. This work is an effort to close the gap. The paper is perhaps the first to advance a description of the literature on engineering education spreadsheet theory. Our review presents a wealth of research opportunities that have, at least, the modest potential to elevate spreadsheet theory and practice in engineering education.

Many faculties are beginning to use spreadsheets to enhance the collaborative component of education, with an increased focus on the learning process [24, 64]. Spreadsheets are a scientific tool that eliminates the tedious and repetitive computational tasks that may be performed manually. For instance, thousands of computations could be carried out and automated in a way that gives precise and timely results and a good opportunity for high quality presentations [3, 23, 39–42]. Hence, spreadsheets as applied to engineering education may be an important area of investigation.

Using spreadsheets provide a unique perspective on the relationship between the component of an equation—an understanding that is essential in engineering analysis. However, the traditional teaching method and manual computation of equations and modelling do not always prove to be effective. For example, the usual approach in structural design optimisation requires that at each iteration of the numerical optimisation algorithm, a set of finite-element analysis equations be solved to compute the objective/constraint functions. Such a nested solution procedure is straightforward because optimisation and analysis processes are kept separate, but wasteful since a complete analysis is performed for each intermediate non-optimal design [18].

Spreadsheets represent a group of application packages used for table-based calculation [67]. It runs simple programmes, manipulates matrices, and aids looping and other high level programming needs [60–62]. Spreadsheets are inexpensive, one that runs on machines of modest specification, and widely available not only to professional engineers but also to learners in universities, colleges and schools as part of the general information technology provision [15]. Again, utilising spreadsheets in engineering education not only makes completing tasks more efficient, but also often achieves a higher degree of accuracy than do humans.

We organise the paper as follows. First, we briefly explaine the need for spreadsheet applications in engineering education. We then reviewed

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the historical development of spreadsheets. Next, we reviewed the literature on spreadsheet application as a general backdrop. Specifically, we base our review on four sections—general engineering, mechanical, electrical, and chemical engineering. We elicit more attention from spreadsheet application researchers to refocus attention on key problems in the engineering spreadsheet applications domain. Finally, we made general remarks and present future directions.

HISTORICAL DEVELOPMENT OF SPREADSHEETS

The English language literature presents spreadsheets to have evolved in corporate America in 1978 with VisiCalc. The honour of discovery of the framework that forms today's widely utilised spreadsheets belongs to a notable former Harvard Business School student, Daniel Bricklin, who needed an electronic spreadsheets for a case study report [64]. This idea transformed into a reality with the assistance of Bob Frankstan, who developed the first electronic spreadsheet, VisiCalc., in 1979.

Due to the limitations of VisiCalc and the ever-expanding knowledge base of researchers interested in spreadsheets, a new spreadsheet, Lotus 1-2-3 software package emerged on the scene to assume the leadership role as the spreadsheet standard. Developed by the IBM Corporation in 1983, Lotus 1-2-3 made the use of spreadsheets easier in view of its added integrated charting, plotting, and database capabilities. The key features of Lotus 1-2-3 include naming cells, cell ranges, and spreadsheet macros, which remediated repetitive and periodic tasks, and also provided the tool to implement a new functionality [65].

The popularity of Lotus 1-2-3 was not contested until 1984 when the Microsoft Corporation stormed the software market with a lot of converts from Lotus 1-2-3. Microsoft Excel then became the first spreadsheets to use a graphical interface with pull-down menus and a point-and-click capability using a mouse-pointing device. This spreadsheet package has maintained an undisputed market leadership [65].

The history of application of Excel in education could be traced to finance and accounting fields [49,55]. As developments proceeded, applications of spreadsheets were extended to engineering education. The electrical engineering researchers and practitioners may be credited with the present level of spreadsheet awareness in engineering education due to their insight, interest, foresight, and extensive applications of the package to electrical engineering problems. Today, spreadsheets is virtually everywhere in the engineering field: from elementary numerical analysis in general engineering to quality control in software, from cache-based parallel processing systems in electrical engineering to heat transfer problems in mechanical engineering.

It also extends from structural calculations in civil engineering to queue simulations in systems engineering, from goal setting in industrial engineering to safety analysis in aeronautical engineering. It could go from process control in chemical engineering to crack detection in material and metallurgical engineering, from well simulation in petroleum engineering to equipment failure rate in agricultural engineering. Fields such as electrical, industrial, mechanical, and civil engineering have extensively utilised spreadsheets in great details. The use of the spreadsheet in engineering has developed as engineering professionals realised the potential contained in the concept.

RELATED STUDIES

Several scholars have investigated into spreadsheet applications in engineering education in recent times and have adopted different approaches to deal with the emerging notions of problem solving, model applications, spreadsheet integrity and its quality control (see [57]). For instance, Green [25] proposed that students and faculties could use spreadsheets to address their problem-solving responsibilities. Boye [1], and Hsiao [32], following Green [25], used spreadsheets to solve iteration problems. Chapman [22] demonstrated spreadsheet applications in problem solving of discrete and fast Fourier transform, and has successfully used it to solve electrical engineering problems. According to these scholars [1, 22, 25], spreadsheets provide a great deal of understanding of the essential features of a model instead of focusing on the mathematical aspects.

In an article on integrity control of spreadsheets, Rajalingham [45] argues that the problem of spreadsheet errors has adverse real-life consequences on engineering education. Building on previous research, Rajalingham [46] proposed an approach that could lead to a better understanding of spreadsheet model assessment, and how to improve its quality. In the following subsections we describe the various contributions of scholars in the general area of engineering, and the specific areas of mechanical, electrical, and chemical engineering.

Spreadsheets applications in engineering in general

In the initial years of the undergraduate engineering programme, students are required to offer general subjects in mechanical, electrical engineering, and mathematics irrespective of their field of specialisation. As such, the contributions of Clements [58, 59], Doak *et al.* [63], Kharab and Kharab [8], Svoboda [37], Boye *et al.* [1], Wiseman and Armstrong [10], and Kral [36] are focused towards this target group.

Clements [58] applied spreadsheets as a tool for teaching elementary numerical analysis with examples that showed how a spreadsheet can be used as a powerful numerical programming system combining the ease of use of the pocket calculator with the power and labour-saving potentials of the computer. Thus, the need to learn, and become proficient in a high level programming language is avoided. Results of a study on applications of spreadsheets to numerical linear algebra provide an indirect support to Clements' proposition [59].

Doak *et al.* [63] investigated animated spreadsheets as a teaching resource at the freshman level. Computer animation using spreadsheets is a powerful teaching tool that avoids unfocused trial and error engagements associated with other interactive computer animation packages. For such packages a practical teaching class could degenerate into a video game, with students blithely entering data and enjoying G*ee-whiz* graphics while managing to ignore completely the underlying physics and mathematics, the understanding of which is the actual intent of the animation.

Kharab and colleague [8] applied spreadsheets programs for the numerical solution of hyperbolic partial differential equations. A complete 123-macro program was applied to obtain the approximate solution of a model problem in electrical engineering. Through user *Macros*, the spreadsheet functioned in the same way as programs written in conventional programming languages. They provided a clear and direct means of entering data and formulas.

Svoboda [37] used spreadsheets to predict and/or minimise the errors due to loading, the availability of standard resistor values, and resistor tolerances. The circuits illustrated trade-off, performance criteria, and nonunique solutions, and the power of spreadsheet programs. In an example, a macro was used to implement an iterative optimisation procedure while in another, minimisation is done by exhaustive search using the table lookup capabilities of the spreadsheet. The final example used spreadsheet's random number generator to perform a Monte Carlo analysis.

Boye *et al.* [1] investigated the problem-solving portion of a two-semester first-year electrical engineering course that used spreadsheets to improve students' problem-solving skills. The goal was to give students a better understanding of engineering concepts and not just mathematical details. In addition, a brief review of the rationale that was used in selecting the hardware and software used in the course was also given.

The research presented here contains several propositions that can be tested using various methodologies devised in the scientific literature. Thus, our discussions here have ignored other applications in conditional looping [19], partial differential equations [21], microprocessor systems [7], numerical methods [26], micros and macros [30, 31], matrix manipulation [23], integer and linear programming [34, 68], engineering product cost determination [18], and other similar studies. These investigations are likely to influence the way spreadsheet applications research is carried out in the future. Hence, we are looking for its expansion and empirical scrutiny. Such an act of inquiry may break new frontiers of knowledge in scientific investigations on spreadsheet applications in engineering education. This may engage researchers in productive studies for decades to come!

Spreadsheets in mechanical engineering

In mechanical engineering, a large pool of problems abound that require the application of spreadsheets for computational ease, accuracy, and timely generation of results [38]. Unfortunately, solutions are rare. There is therefore a challenge to researchers to shift the focus from the traditional orientation in teaching and learning mechanical engineering courses to modern, result-oriented, and effective perspectives. In the literature on spreadsheet applications, scholars have tended to generate studies that focus exclusively on heat transfer and conduction. This bias is apparent in the studies due to Schumack [53], Antar and colleagues [51, 52], and Tai [44] and Davies [2].

Schumack [53] considered the problem of teaching heat transfer using automotive-related case studies with a spreadsheet analysis package. He used five automotive-related projects to teach the principles of heat transfer. Students were required to perform their engineering calculations with the spreadsheet package Microsoft Excel. The objectives were to increase student understanding and interest in heat transfer principles by presenting problems in a familiar context, to improve the student's ability to use spreadsheets as an engineering analysis tool, and to provide experience in dealing with the open-endedness of real engineering problems.

Antar and Mokheimer [51] presented a detailed methodology and different techniques for simply utilising spreadsheet programs in heat conduction analysis. An evaluation of analytical and numerical solutions of heat conduction problems for one- and two-dimensional steady and transient heat conduction problems were investigated using a new technique of marching the transient numerical solution with time in a single-layer spreadsheet. This concept was extended in another paper to a three-dimensional heat conduction problem [52]. Here, an implicit numerical scheme was used and user-defined macros were designed and executed in a single-layer sheet. The method allows the use of all standard boundary conditions such as constant surface temperature, specified heat flux, thermal insulation, convection and/or thermal radiation. The method also allows the user to incorporate nonlinear boundary conditions such as thermal radiation with no further simplification which otherwise would require further effort to model. Kharab's work [9] is an extension of the heat conduction studies with specific attention paid to the two-dimensional aspect of the problem.

Tai [44] illustrated an economic alternative approach where the finite-element equations are formulated as part of the optimisation problem by treating the unknowns as design variables and equations as equality constraints. This integrated problem was solved using a spreadsheet application that serves as a highly suitable platform for integrating and solving the optimisation and analysis simultaneously since all spreadsheet cells are interlinked. The techniques represent a very convenient tool to learn about design optimisation, and to gain physical insight into their design problems and perform design optimisation routinely in their work.

Electrical engineering: spreadsheets applications

For electrical engineering, numerous documentations abound in the areas of modelling and analysis of systems. There is a research pool focusing on electromagnetism, signal and linear systems, logic networks, sinusoidal steady-state transmission line and optics problems. The modelling efforts offer a direct approach to understanding systems behaviour and have encouraged a quantitative feel for the underlying mathematics [14–16]. Also, a compendium of studies exists in some electrical engineering applications [50, 54], antenna design [43], failure distribution [29], high level mixed mode simulation [56], analog computer simulation [47], and experimental analysis on causal filters [48] that have not been rigorously reviewed here. Interested scholars could consult the references.

In an influential article Yamani and Kharab [11] described how a spreadsheet program assisted electromagnetic education at the undergraduate level. Using the power of the 123 macros, a menu-driven spreadsheet program was used to compute the solution of some electrostatic boundary value problems for an introductory-level electromagnetic course. They noted that with the on-screen numerical and visual feedback, and the ease of entering data, students were able to take a close look at the effects of varying the input data of the model problems.

In a study by Bissell and Chapman [13], spreadsheets were applied in telecommunication, signal processing, and control engineering. Examples were drawn from frequency response calculations, control systems design, digital processes and Fourier series analysis. Extensive application of spreadsheets was demonstrated using the amplitude frequency response of a low powered system with an undamped natural angular frequency of 50 rad/s and a damping ratio of 0.3. Spreadsheets were also used to calculate the frequency response of a system of multi-cascaded components: integrators, delays, and phase leads. The digital-filter simulation problem was solved using spreadsheets with the output sequence tabulated. Spreadsheets were also used to calculate the sine and cosine components of a repeating 12-bit binary sequence transmitted as a unipolar NRZ rectangular waveform. The arguments presented by Bissell and Chapman above are consistent with Wong's [66].

In the area of linear system analysis, Stanton *et al.* [12], and El-Hajj and Kabalan [5] have carried out prominent research. Stanton *et al.* [12] used the power of PC-based spreadsheet programs to aid students' understanding and cognitive development. They examined the Fourier series and allowed students to see graphically how the harmonics of the series add and subtract to form a new periodic waveform. Then students worked through the path to accompany the condition of two signals. The work demonstrated how students could focus on gaining a conceptual understanding of signal and linear system analysis while de-emphasising the rigours of developing a user interface that is a common problem when using structured programming languages.

El-Hajj and Kabalan [5] used pictorial simulation of the mathematical performance of an integrator. A connecting method using integrators was used to symbolise different blocks of the systems, each representing a given transfer function. These blocks were then connected according to the signal flow and the interrelationship existing between them. As a result, the output of the system in response to any given input and configuration was evaluated. Low cost, flexibility, and simplicity characterise this method.

For simulation of logic networks, prominent studies include that of El-Hajj and associates [4, 6]. The El-Hajj research group presented an improved method for simulating logic networks using modern spreadsheet programmes. The user interface was customised using toolbar menus, help, dialog sheets, and other advanced spreadsheet features. This study is of a conceptual consistency with another paper by El-Hajj and Kabalan [4]. They used this method to simulate combinational, sequential, synchronous and asynchronous networks. The characteristics of the method make it significant as an important tool in the analysis, design and test of logic networks in education environments.

On sinusoidal steady-state transmission problems, Shapiro [28] showed how a spreadsheet on a personal computer could be used. It gives students the experience of programming the equations rather than relying on special-purpose software written by someone else.

Bissell [17] studied the powerful features of spreadsheet including its graph-plotting ability. The strengths of spreadsheet in making modelling assumptions explicit and the ability to reflect problem or solution structure were important foci. The appropriateness of spreadsheets in recursive models, digital systems, discrete event simulation and exploring model validity were considered. The attraction of spreadsheets as graph plotters lie primarily in the way the physical structure of the spreadsheet can aid understanding: a spreadsheet removes the drudgery of repeated calculation and the potential errors of graph plotting by hand. A spreadsheet simulation was designed that did not presuppose knowledge of calculus. An example shown in Bissell's paper related z-plane pole positions to transient response sequence of a discrete linear system. It was explored using a spreadsheet. Applications were demonstrated in simulating a tennis game, the bunching of buses on a crowded route, pest control and scheduling problems.

In another research on modelling, Bissell [16] treated five aspects of the work in:

- heuristic modelling;
- the relationship of modelling assumptions with spreadsheets cell;
- system topology, solution strategy and spreadsheets structure;
- discrete event simulation;
- computational aspects.

Heuristic modelling considered data on the survival of 10,000 components subjected to testing. Initially, there is a high failure rate, but after a few days the percentage daily survival rate settled down to a constant value of about 0.85. The spreadsheet used permitted such interesting and useful models to be investigated without the analytical mathematics that so many novice students find so daunting. Next, the optimisation problem of finding the maximum area of a rectangle with a perimeter of 18 units was tackled. On the aspect of modelling assumption relationships with spreadsheet cells, a model of growth and decay is considered. The classic continuous model discussed is based on modelling assumptions such as growth rate being proportional to pollution or fractional growth rate declining linearly with increasing population. Traditionally, knowledge of calculus has been required before tackling them. All this changes with a spreadsheet.

Diab [35] used spreadsheets for the performance analysis of cache-based multiprocessors for general-purpose computing. The Lotus 1-2-3 spreadsheet was used to study the behaviour of the cache miss ratio and the bus bandwidth with respect to the cache line size. Its low cost; flexibility and simplicity characterise the simulation. The suitability of this tool for educational purpose and its use in an advanced computer architecture course were also discussed.

Spreadsheet applications in chemical engineering

In chemical engineering, the work by Edgar [64] presents an interesting insight to spreadsheet applications in the field. The writer presented the historical basis for the popularity of spreadsheets in recent times. In the specific application to chemical engineering, Rives and Lacks [20] considered the subject of teaching process control with a numerical approach based on spreadsheets. This is an improvement on the traditional method for teaching process control courses. The traditional approach uses analytic techniques based on laplace transforms to solve the relevant differential equations manually .The mathematical manipulation involved in these analytical solutions is so complex and non-intuitive, however, that students can lose sight of the physical significance of the results. Numerical solution offers a remedy to this problem and can be used in conjunction with traditional analytic solutions to strengthen the instruction of process control. They emphasised that numerical solutions are not intended to replace analytical methods, but should instead be used in addition to analytical methods. Apart from the above studies in this subsection, other workers [27] have explored the field in a great detail.

CONCLUSIONS AND FUTURE DIRECTIONS

General conclusions

The engineering education literature has been advanced in a significant way due to the impact of researchers who have conducted scientific studies and investigations related to spreadsheet applications. The younger investigators should follow the path of our established researchers in the field who have utilised sound methodologies in conducting and completing their research projects. Knowing the fact that there is no perfect research, we all need to improve upon our research. In addition, we need to continuously explore and improve our teaching skills and course contents with the new features and technology embedded in spreadsheets.

In this paper, we reviewed the relevant research that have been carried out to date and proposed some top priority research question for empirical, theoretical and conceptual scrutiny by the members of the engineering education community. Our results show that spreadsheet applications are wide ranging, covering disciplines of electrical, mechanical, nuclear, materials, metallurgical, marine, industrial, structural, chemical, aeronautic and civil engineering. It is gradually spreading to some relatively young disciplines such as mechatronics and biomedical engineering, etc.

An institution's sense of fulfilment, its true effectiveness, success and failure in its role within the community, state, nation, and world at large are realised only when certain conditions are met. Institutions are required to be effective and use data in decision making to achieve excellence and mission fulfilment. This is strongly aided with the power of information technology where a spreadsheet application is at the central of affairs.

The consensus reached at global conferences has helped to raise awareness of the need for a more intense introduction of spreadsheets into the engineering education curriculum. The application of spreadsheets to modelling problems can facilitate the deepening of students' understanding of models and modelling while using the language of engineering and technology directly.

The participation of all stakeholders needs to be ensured in order to have improved growth in the number of students and faculties using spreadsheets. The literature on spreadsheet applications in engineering education identifies and classified key future actions into those that relate to teaching and learning of spreadsheets.

In mechanical engineering, there is a wide pool of opportunities in applying spreadsheets. Strength of materials, mechanics of machines and other mechanical engineering areas are crying out for spreadsheet applications. This suggests that strong theories are needed having a single or small set of well-developed, logically linked research ideas that lend themselves readily to empirical testing. To be successful, new theories should exhibit continuity with previous works as well as sufficient novelty to make them distinctive.

The conclusions drawn from various researches conducted in the spreadsheet applications literature in engineering is that there is a significant interest in the application of spreadsheets in both simple and complex engineering models and problems. Thus, spreadsheets have aided an increased understanding of researchers, students, and faculty members. There is also a uniform criterion for defining the applicability of spreadsheets to engineering problems.

Future directions

From the findings of this study, it is recommended that many areas warrant investigations. A top priority research is the development of various versions of customised spreadsheet application software on specific problems. It should be comprehensive, automated, and useful as a tool and be accessible electronically. An interesting dimension in the spreadsheet application software development could be the ability for system users to access data entry screens, reports, and data submission modules through an Internet browser. Engineering spreadsheet application with CD-ROM software could be put in place and its functionality ported over to a server, enhanced and made available at different websites. It could be christened according to the problem solved (i.e. www.spreadsheetsappleng.com). It may be developed such that no special software is required and the operator can access the system from anywhere on the Internet.

Although fields such as materials and metallurgical engineering have been in existence for several decades, intellectual discussions of spreadsheet issues related to the field are scarce. Only traces of applications limited to the phase transformation diagrams of temperature, time, and transformation (TTT) is observed from the literature. There are opportunities to extend current applications of spreadsheets to the phase diagrams of Iron-Iron-Carbide in order to permit us to trace the assignable causes of failures in structural systems. With the emergence of nanotechnology and polymers, there is a wide spectrum of application opportunities for spreadsheets in materials and metallurgical engineering.

The future long-term condition of spreadsheet applications in engineering depends very much on the actions that are taken in the current decade. To defer action beyond this time scale will commit a significant proportion of our engineering undergraduates to a downward spiral of decline in spreadsheet understanding. Rescue from this will be financially and economically prohibitive. Imagination and innovation are required as well as financial resources if a new generation of information technology illiterates on spreadsheet applications is to be avoided.

Clearly, we do not attempt to replace the existing literature by any means, but rather build on it. The motivation behind this research is to correct the present state of fragmentation of spreadsheet methodology. Many of the most influential articles on spreadsheet applications appear in journals as diverse as simulation, information systems, electrical engineering, *IEEE Transactions on Education, International Journal of Mechanical Engineering, International Journal of Electrical Engineering Education, International Journal of Applied Engineering Education, Computer Applications in Engineering Education*, etc.

Course administrators should encourage individual and group projects in spreadsheet applications. These are principal vehicles for learning how to employ basic analytical tools and procedures embedded in spreadsheet applications. Students could be organised into teams and instructed on the use of some important features in spreadsheets and methods appropriate to completing tasks at various stages of learning.

In view of the increasingly tight financial constraints placed on educational administrations, there is a continued need and pressure placed on institutions of higher learning to demonstrate its commitment to quality. Hence, high quality instructions and learning must be realised in the area of spreadsheet applications since mastery of spreadsheet skills is advantageous compared with some other computer software programmes. Spreadsheet users need not expend too much effort on coding in a standard computer language. The spreadsheet rather than a hand-held calculator accomplish the numerical effort.

Advocacy should be undertaken to improve our understanding of macros and the programming aspects of spreadsheets as related to engineering education. Within this framework, a clearer understanding of how models work, modification and improvement requirements will be achieved. Students and teachers should be provided with computer facilities fully loaded with the latest versions of spreadsheets. The aim is to improve interaction with the computer with easy access to spreadsheet packages.

Freshman engineering students, the bulk of undergraduates that will finally mature into faculties and professionals in the long-term future must be well trained and exposed to the skill requirements of spreadsheets. Therefore, an integrated programming and investigaton must be made to ensure the full involvement of freshman engineering undergraduate.

One of the entry points for exposing freshman-engineering undergraduates to skilful use of spreadsheets is the introduction of its concept and use in the general engineering courses such as numerical methods and differential equations. With this, students could avoid the difficult task of programming. Here, they have a greater understanding and interaction with the computer.

International fund-assisting organisations should embark on programs aimed at increasing the knowledge base of university students and faculties in engineering spreadsheet applications. They should provide guidance and assistance in defining programmes and actions to address spreadsheet application in engineering education. These should assist universities in selecting the policy, strategy and programme actions for addressing spreadsheet application in engineering education.

Universities must redefine their admission requirements to include additional criteria of computer literacy for admissions. A more specific requirement could be the demand for spreadsheet literacy from potential undergraduates into engineering-based courses before admissions. This will force many into learning about spreadsheets. Some may demonstrate competency.

REFERENCES

1. A. J. Boye, P. F. Williams and R. J. Soukup, Using spreadsheets to teach problem solving in a first year class, *IEEE Transactions on Education*, **36**(1), Feb. 1993, pp. 68–71.
2. A Davies, Using a spreadsheet to investigate models of heat conduction and vibrating strings, *Teaching Maths and Its Applications*, **12**, 1993, p. 179.
3. A. E. DiAntonio, *Spreadsheet Application*s, Prentice-Hall (1986).
4. A. El-Hajj and M. Hazim, On using spreadsheets for logic networks simulation, *IEEE Trans. Educ.*, **41**(4), Nov. 1998, pp. 311–319.
5. A. El-Hajj and K.Y. Kabalan, Time domain analysis of linear systems using spreadsheets, *IEEE Trans. Educ.*, **38**(4), Nov 1995, pp. 317–320.
6. A. El-Hajj and K. Y. Kabalan, A spreadsheet simulation of logic networks, *IEEE Trans. Educ.*, **34**(1), Feb. 1991, pp. 43–46.
7. A. El-Hajj, K. Y. Kabalan and H. Diab, A spreadsheet educational tool for microprocessor systems, *Computer Applications in Engineering Education*, **3**(3), 1995, pp. 205–211.
8. A. Kharab and R. Kharab, Spreadsheet solution of hyperbolic partial differential equations (for EM field calculations), *IEEE Trans. Educ.*, **40**(1), Feb. 1997, pp. 103–110.
9. A. Kharab, Use of a spreadsheet program in a two-dimensional heat conduction problem, *Computer Methods in Applied Mechanics and Engineering*, **122**, 1995, pp. 173–181.
10. A. N. Wiseman and PK Armstrong, Introducing discrete information theory using spreadsheets, *Teaching Maths and Its Applications*, **12**, 1993, p. 130.
11. A. Yamani and A. Kharab, Use of a spreadsheet program in electromagnetic, *IEEE Trans. Educ.*, **44**(3), August 2001, pp. 292–297.
12. B. J. Stanton, M. J. Drozdowski and T. S. Duncan, Using spreadsheets in student exercises for signal and linear system analysis, *IEEE Trans. Educ.*, **36**(1), Feb. 1993, pp. 62–68.
13. C. C. Bissell and D. A. Chapman, Spreadsheets as a learning aid in engineering education, *CAEE 93 Int. Conf. Computer-Aided Engineering Education*, Bucharest, Romania, September 1993.
14. C. C. Bissell and D. A. Chapman, Modelling applications of spreadsheets, *IEE Review*, July/August 1989, pp. 267–271.
15. C. C. Bissell, Technology for maths for technology: the role of spreadsheets, *Technology and the Teaching of Mathematics Conf.*,, Birmingham, UK, September 1993.
16. C. C. Bissell, *Spreadsheets in Engineering Education: Mathematics, Modelling and Simulation*, Report No. SAG/1994/RR37/CCB, The Faculty of Technology, The Open University, Milton Keynes, UK (1994).
17. C. C. Bissell, Spreadsheets in the teaching of information engineering, *Engineering Science and Education J.*, April 1994, pp. 89–96.
18. C. L. Croskey, Spreadsheet illustration of engineering economics, *IEEE Trans. Educ.*, **31**(4), Nov 1988, pp. 270–275.
19. C. R. Thomas, Three methods of performing conditional looping in a spreadsheet, *Int. J. Eng. Educ.*, **8**(4), 1988, pp. 271–277.
20. C. Rives and D. J. Lacks, Teaching process control with a numerical approach based on spreadsheets, *Chemical Engineering Education*, 2002, pp. 242–248.
21. C. Y. Lam, Spreadsheet approach to partial differential equations, Part 1: Elliptic equation, *Int. J. Eng. Educ.*, **8**(4), 1988, pp. 278–287.
22. D. A. Chapman, Spreadsheet demonstration of discrete and fast Fourier transforms, *Int. J. Electr. Eng. Educ.*, **30**(3), 1993, pp. 211–215.
23. D. G. Hendry and T. R. G. Green, Creating, comprehending, and explaining spreadsheets: a cognitive interpretation of what discretionary users think of the spreadsheet model, *Int. J. Human-Computer Studies*, **40**(6), June 1994, pp. 1033–1065.
24. D. J. Power, A brief history of spreadsheets. http://www.DSSResources.com
25. D. R. Green, Solving iteration problems using a spreadsheet, *Teaching Maths and Its Applications*, **12**, 1993, p. 22.
26. D. R. Green, Numerical methods using a spreadsheet, *Teaching Maths and Its Applications*, **13**, 1994, p. 68.

27. E. M. Rosen and L. R. Partin, A perspective: the use of the spreadsheet for chemical engineering computations, *I&EC Chemistry Research*, **39**(6) June 2000, pp. 1612–1613.
28. F. R. Shapiro, The use of a spreadsheet for sinusoidal steady-state transmission line and optics problems, *IEEE Trans. Educ.*, **36**(2), May 1993, pp. 269–272.
29. E. G. John and R. I. Grosvenor, Failure distribution curve fitting using spreadsheet add-ins, *Int. J. Electrical Eng. Educ.*, **38**(2), April 2001, pp. 165–172.
30. F. S. T. Hsiao, Micros in mathematics education—uses of spreadsheets in CAL, *Int. J. Math. Educ. Sci. Technol.*, **16**, 1985. p. 705.
31. F. S. T. Hsiao, An evaluation of spreadsheet macros for CAI with applications to matrix multiplication, *Collegiate Microcomputer*, **5**, 1987, p. 333.
32. F. S. T. Hsiao, A computational design of some matrix iterative methods using spreadsheets, *J. Amer. Inst. Ind. Eng,.* **19**, 1987, p. 17.
33. F. S. T. Hsiao, Implementation of the Gauss-Jordan method of matrix inversion by spreadsheet macros, *Int. J. Math. Educ. Sci. Technol.*, **19**, 1988, p. 729.
34. F. S. T. Hsiao, The simplex method of linear programming on microcomputer spreadsheets, *College Maths J.*, **20**, 1989, p. 153.
35. H. Diab, Simulation of cache-based parallel processing, *Int. J. Eng. Ed.*, **14**(2), 1998, pp. 136–144.
36. I. H. Kral, *Excel Spreadsheets for Engineers and Scientists*, Prentice-Hall (1991).
37. J. A. Svoboda, Using spreadsheets in introductory EE courses, *IEEE Trans. Education*, **35**(3), Aug 1992, pp. 226–229.
38. J. M. Hale and C. Grant, A course in the use of computer spreadsheets for mechanical engineering students, *Int. J. Mechanical Engineering Education*, **21**(2), 1993, pp. 146–155.
39. J. Walkenbach, *Microsoft Excel 2000 Power Programming with VBA*, IDG Books Foster City, CA (1999).
40. J. C. Nash and T. K. Quon, Issues in teaching statistical thinking with spreadsheets, *J. Statistics Education*, **4**(1), 1996.
41. J. Gianini, J. C. Nash and T. K. Quon, Statistical issues in spreadsheet software, *1994 Proc. Statistical Education Section*, 1995, American Statistical Association, Arlington VA. Pp. 238–241.
42. M. L. Cuttle, C. P. L. Young and S. B. Heath, A practical introduction to creating courseware with Microsoft Excel, *CTI CLUES*, University of Aberdeen.
43. M. Hagler, Spreadsheet program in antenna design application, *IEEE Trans.*, **AP–30**, 1986, pp. 585–587
44. K. Tai, Integrated design optimisation and analysis using a spreadsheet application, *Int. J. Mechanical Engineering Education*, **27**(1), January 1999. http://www.me.umist.ac.uk/ijmee/27-1p3.htm
45. K. Rajalingham and D. Chadwick, Integrity control of spreadsheets: organisation & tools, *Proc. 2nd IFIP TC-11 Working Group 11.5 Working Conference on Integrity and Internal Control in Information Systems*, November 1998, Virginia, USA, Kluwer Academic Publishers, pp. 147–168.
46. K. Rajalingham, D. Chadwick, B. Knight and D. Edwards, An approach to improving the quality of spreadsheet models, *Proc. 7th Int. Conf. Software Quality Management SQM'99*, March 1999, Southampton, UK, British Computer Society, pp. 117–131.
47. K. Y. Kabalan, A. El-Hajj, H. Diab and S. Fakhreddine, Analog computer simulation using spreadsheets, *Simulation*, **68**(2), 1997, 101–106.
48. K. Y. Kabalan, H. Diab, A. El-Hajj and H. Tabbara, Stability analysis and minimum phase testing of causal filters using spreadsheets, *Int. J. Eng. Educ.*, **12**(5), 1996, pp. 382–388.
49. L. Healy and R. Sutherland, *Exploring Mathematics with Spreadsheets*, J. Murray (1992).
50. L. R. Huelsman, Electrical engineering applications of microcomputer spreadsheets analysis programs, *IEEE Trans.*, **E-27**, 1984, pp. 86–92,
51. M. A. Antar and E. M. Mokheimer, On the use of spreadsheet in heat conduction analysis, *Int. J. Mechanical Engineering Education*, **28**(2), 2000. http://me.umist.ac.uk/ijmee/28-2.htm
52. M. A. Antar and E. M. Mokheimer, Spreadsheet modelling of transient three-dimensional heat conduction with various standard boundary conditions, *Int. J. Mechanical Engineering Education*, **30**(1), 2002. http://www.me.umist.ac.uk/ijmee/30-1p3.htm
53. M. R. Schumack, Teaching heat transfer using automotive-related case studies with a spreadsheet analysis package; *Int. J. Mechanical Engineering Education*, **25**(3), 1996, pp. 177–196.
54. N. D Rao, Typical applications of microcomputer spreadsheets to electrical engineering problems, *IEEE Trans.*, **E-27**, 1984, pp. 237–242.
55. N. Kantaris and and P. R. M. Oliver, *Excel 5 Explained*, Bernard Babani Publishing, (1994).
56. P. H. Saul, The spreadsheet as a high-level mixed mode simulation tool, *Electronic Engineering*, 1991, pp. 549–555.
57. R. R. Panko and R. P. Halverson, Jr., Spreadsheets on trial: a framework for research on spreadsheet risks, *Proc. 29th Hawaii International Conference on System Sciences*, Jan. 1996, Maui, Hawaii.
58. R. R. Clements, *Spreadsheets as a Tool for Teaching Elementary Numerical Analysis*, University of Bristol, Department of Engineering Mathematics, Report EM/RRC/91/1, (1991)
59. R. R Clements, Teaching topics in numerical linear algebra using spreadsheets, *Int. J. Math. Educ. Sci. Technol.*, **22**, pp. 1003 (1991).
60. R. Jackson, Modelling population growth using a spreadsheet, *Teaching Maths and its Applications*, **12**, 1993, p. 74.
61. R. Jackson and J. T. Callender, Estimators: a spreadsheet investigation of bias, *Teaching Maths and Its Applications*, **13**, 1994, p. 78.
62. R. Jackson, A spreadsheet approach to complex transformations, *Teaching Maths and Its Applications*, **12**, 1993, p. 174,
63. R. B. Doak, J. McCarter, M. Green, S. Duerdeen, D. Evans, R. Roedel and P. Williams, Animated spreadsheets as a teaching resource on the freshman level (2000). (Electronic article.)
64. T. F. Edgar, Chemical engineering education and the three C's: computing, communication, and collaboration, *Annual Meeting*, Los Angeles, CA, November 12–17, 2000.

65. T. T. Phan, Technical considerations for the evaluation of electronic spreadsheets for complying with 21 CFR Part II (2003). (Electronic article.)
66. Y. K. Wong, Application of a spreadsheet program to control system design, *Int. J. Elect. Eng. Educ.*, **29**, 1992, pp. 16–23,
67. S. J. Davis, Tools for spreadsheet auditing, *Int. J. Human-Computer Studies*, **45**, 1996, pp. 429–442.
68. Y. Kuo and W. Kuo, Application of electronic spreadsheets to linear and integer programming, *Int. J. Applied Engineering Education*, **3**(6), 1987, pp. 563–575.

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