A Novel Approach to Generate Assessment Papers and Solution Schemes for Design Based Engineering Modules

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Abstract—**Introduction of computers into engineering curriculum dates back to late 19th century and the results of the attempt are now being seen in all over the world, particularly, in engineering field of study. Researchers and academicians, thereafter, continue to use a number of computer aided tools to represent their findings and research outcomes. In this attempt, computing technologies are put into effective use to design student assessment papers and their evaluation tools for a particular module which is design based. In this way, customized and individual assessment paper is generated using a unique set of design data pertaining to the problem and corresponding solution scheme and relevant details of the output data along with respective design drawings are produced. This will definitely help teachers and faculty members in an engineering discipline to design high quality assessment papers in technical education and expose students to resort to modern methods of computing tools to perform engineering tasks. Software interface and package are developed using Microsoft Excel® software effectively to display the input design conditions and parameters related to a particular student. Eventually, evaluation phase is designed that encompasses design results and sketches to countercheck the results obtained manually by each individual student. The objective of this task is to expose students and academicians of this novel method of conducting assessment and utilise evaluation methods in their University in order to differentiate the gravity of assessment paper for each individual student. Presently, this approach is designed for a module entitled Mechanical Engineering Design and efforts will be directed in future to extend it to other modules as applicable. One of the significant benefits of this modern pedagogical approach applied with innovative technology is enhancement of core competencies of teachers and researchers that nurtures assessment environment. Other perceived outcomes of this approach include uniqueness in student assessment paper, reduced evaluating time, accurate marking of student papers and quick feedback to students to improve their performance. In all, better management of module through application of computing technologies would be the core advantage.**

Keywords-computer assisted assessment, application of Microsoft Excel® software, students assessment;

I. INTRODUCTION

Modern computing technologies could be put into an effective use for designing assessment papers and their evaluation tools at various levels of study and the degree of application of these technologies can range from just management of the assessment information to a fully automated assessment system. The purpose of using technology for designing the assessment package is to enable information to be presented in different ways to meet the needs of different audiences such as teachers, students, course organisers and external examiners. By doing so, not only the quality of presentation of assessment papers but more importantly the range and scope of their content can be improved by utilising technology appropriately. On the other hand, a fully automated assessment system comprises automation of all aspects of the system from the assessment to the processing and administration of the marks, including the overall management of assessment information. Computing Technology is an ideal tool to develop assessment materials for individual students and small or large cohorts and track their status of download or receipt of assessment paper easily along with evaluation of student submissions.

In this attempt, application of Microsoft Excel® software into generating assessment and evaluation package is envisaged for a design based module at an undergraduate engineering programme level. In this novel approach, design inputs and conditions pertaining to design of machine component or mechanical element or system (ex. *power screws*) are listed down which are unique to each student. Assessment paper specific to each student will be generated once student picks his/her student number. The question paper will feature design input data and corresponding design sketch of the system in question with all relevant tasks and requirements/expectation from students.

In this Integrated System for Assessment (ISA), the tasks expected to be performed by students and the design inputs/data are customized to each student and held electronically. Students can refer to it or download the

assessment paper whenever needed. Students are not granted any access to change or modify the question or design inputs/data. Once the students select their student number and press *enter* option, the paper is generated and ready for printing. Every student can know how the assessment paper is framed for him or her and can discover how different it is for him/her from others. In this way, the assessment integrity is very much ensured and maintained since evaluation activities are critical to effective development of interactive assessment systems. Further, the solution schemes specific to each student are generated that would provide the outcomes of the students work whether the design is feasible and satisfactory.

The following five major facts were considered in development of the course work assessment papers.

1. Assessment must encourage and reinforce learning.
2. Assessment must measure achievement of the stated learning objectives (LO's).
3. Assessment must enable robust and fair judgments about student performance.
4. Assessment practices must be fair and equitable to students and give them the opportunity to demonstrate what they have learned.
5. Assessment must maintain academic standards

II. BACKGROUND

The core aim of teaching fraternity is to deliver to students a high quality education containing updated technology, information and methods in order to cope with the rapid development and growth in application areas. In addition, assessment, evaluation and feedback conducted by teaching faculty against student submissions also gain center stage as most of the employment and placement opportunities are heavily dependent on student Grade Point Average (GPA). Key attributes that are focused during the assessment and evaluation process include adequate technical challenges on the assessment paper, clear tasks/expectations from students and

It is stated by Summons et al [1] that automation of assessment and marking is an academic goal of a university to ensure that student learning outcomes are achieved to their maximum potential. Attainment of academic goals however, can often be in conflict with attempts to realise administrative or business goals, as these may be perceived as being easily achieved through rationalisation of academic costs. The modern university must find a balance in the optimisation of these goals. This optimization work was based on the background theory laid by Cranitch [2] that "...with large numbers of students with different learning styles, there is a need to develop instructional arrangements that maximize student learning, while trying to minimise the cost in terms of time, effort and money". Practically this may mean trying to maximise individual learning outcomes within very large classes, while trying to cope with the problems associated with large classes. One method of doing this is to reduce the logistic load or the management complexity of large classes for assessment management as demonstrated by Oliver & Mitchell [3].

Reeves and Hedberg [4] mentioned that the evaluation process should guide the creative development process by providing timely and insightful information about the status of the design ideas and the quality of their implementation. Stav [5] described that in the formative and summative evaluation phases used Smartphones, which is a new learning outcomes evaluation model where test results for a class are turned into an active, creative and collaborative learning process by the use of immediate feedback. Ćukušić, Garača and Jadrić [6] validated the effects of online self-assessment tests as a formative assessment strategy in one of the first year undergraduate courses. They also specified that achieved students' results such as test scores and pass rates are compared for three different generations for the same course but also judged against the exam results of other courses taught in the same semester. Their analysis pointed out that there was a statistically significant difference between the groups for half-semester tests and exam pass rates after online self-assessment tests were introduced. Positive effects on students' success were approximated for the overall institution using a simulation model. Results point out that a small increase in pass rates could significantly impact the overall success i.e. decrease of dropout rates.

Computer based assessment and evaluation package is designed using Excel software to enable both easy marking the student submissions and to eliminate the collusion commonly found in written reports particularly when assessment and marking are done for bigger cohorts in a class. The evaluation tool generates a solution scheme automatically based on the student number chosen and evaluates the feasibility of the design, allowing for manual checking of the student work by the tutor. Fig. 1 shows the main page of the interface wherein each student picks his/her student number and generate the print-ready assessment paper. Each assessment paper will consist of student name, student number and other details concurrently. The proposed system in this attempt is found to be very convenient for our department wherein efficient and straightforward means of communication such as electronic mail and common Learning System (much like Blackboard®) are available. Students and tutors can be informed through e-mail to download the assessment materials and when students are absent, they can receive the file when they next access their CCE learning system or by email.

III. DESCRIPTION ON SOFTWARE PACKAGE DESIGN

The software application is designed and developed using Microsoft Excel® software and interfaced with students registered on Mechanical Engineering Design module. The objectives of this attempt are twin-folded. Firstly, the package

will generate assessment paper individually for each student so that the questions are unique avoiding collusion and copying among the students and secondly, solution scheme for each individual assessment paper is generated that will be used as a marking scheme for module tutors.

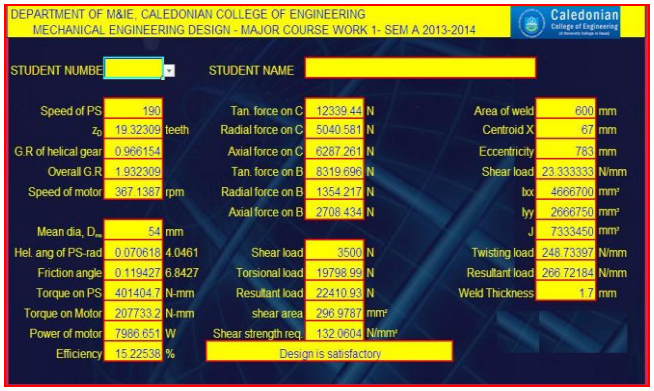

FIGURE 1 MAIN QUESTION PAGE OF THE SOFTWARE PACKAGE

The assessment paper is generated by linking a common template (containing a number of variables are embedded in specific places on the assessment question where the unique values are to be present for each student) with voluminous data related to the design problem and parameter fed from the excel file. These data are generated suitably considering various design parameters and possible range of values for each parameter. A sample of design parameters and design data corresponding to one particular student on various machine elements or mechanical systems is tabulated in Table 1 for a quick reference.

FIGURE 2 MAIN SOLUTION PAGE OF THE SOFTWARE PACKAGE

Each student will select his/her student number from the select box and preview the assessment paper which is having unique variable values pertaining to the design problem in question. A generic design drawing of the mechanical system, element or component (for ex. Power Screw in this case) will be displayed under the main interface page of the system as shown in Fig. 3.

TABLE I. DESIGN PARAMETERS AND THEIR INPUT VALUES

Parameters	Values	Parameters	Values	Parameters	Values	Parameters	Values
1. Gear design Inputs		2. Power screw design Inputs		3. Bolt design inputs		4. Weld design inputs	
Gear ratio A&B	1.5	No. of start	2	Diameter	18	b	200
Nor. Module A	3	pitch	10	Load factor	1.5	d	200
Face Width	22.5	D_{os}	60	p_a	160	Start of weld	800
DB	120	Screw	0.11	No. of bolts	8	Load factor	1.5
z_C	20	Velocity	0.038	Eccentricity	850		
Nor. Module C	2	Load	30000	X	100		
Pre. Angle (f)	20	D_{oc}	100	Y	100		
Helix angle (q)	25	D_{ic}	40	p_w	215		
Center distance C&D	66.2	Bearing	0.21				

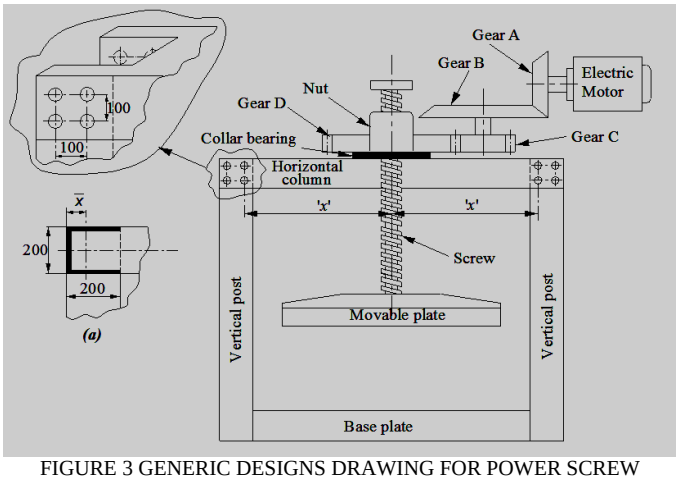

FIGURE 3 GENERIC DESIGNS DRAWING FOR POWER SCREW

IV. DESIGN INPUTS AND FORMULAE

The software package in this paper was developed for a design based engineering module in the field of mechanical engineering. Since it is a design based module, it involves a lot of design data, information and design rules/formulae related to the design process. Table II presents a set of input and formulae used for a particular design activity (i.e., power screw) with the their equivalent encryption format in Excel file.

Further, the complete flow of the design process adopted in this spreadsheet is illustrated in Fig. 5 and it is very clear from this flow that each and every aspect of the design process is taken care meticulously. Also the final outcome of the student work is compared with solutions that are generated by the software package.

Evaluation of the student work is very transparent and every student will be convinced of the marking process. Since evaluation activities are critical to effective development for students to further their knowledge and learning, providing timely feedback in terms of useful insights on the design ideas of students and the quality of their implementation will become very much essential.

TABLE II. FORMULAE AND EXCEL SYNTAX – A SPECIFIC CASE

Description	Formula used	Excel syntax
Rotational speed of power screw	$\frac{velocity}{lead} = \frac{0.038}{2\times10^{-3}}$	=(AL3*1000/(AH3:AH10*AI3))*60
Mean Diameter	$D_{ms} = D_o - P/2 = 60 - 10/2 = 55\,mm$	=AJ3-(AI3/2)
Lead angle of the screw	$\therefore \tan\theta = \frac{l}{\pi D_{ms}} = \frac{2\times10}{\pi\times55} = 0.1157$	=TANH((((AH3*AI3)/(PI()*BJ3)))
Centre distance, a, Calculation of Zd	$\left(\frac{m_n}{\cos\varphi}\right)\times\left(\frac{z_c+z_D}{2}\right)$	=(2*AG3*COS(AF3*PI()/180)/AD3)-AC3
Gear ratio of helical gear		=BF3/AC3
Torque on power screw	$W\tan(\phi+\theta)\frac{D_{ms}}{2} + W\mu_c\frac{D_{mc}}{2}$	=((AM3*(TAN(BK3+BL3))*(BJ3/2))+(AM3*AP3*((AN3+AO3)/2)/2))
Torque on electric motor	$\frac{497.23}{gear\ ratio} = \frac{497.23}{4} = 124.3\,N\text{-}m$	=BM3/BH3
Power required for electric motor	$\frac{2\pi NT}{60} = \frac{2\pi\times456\times124.3}{60}$	=(2*PI()*BI3*BN3)/60000
Torque on power screw without friction	$W\tan\theta\frac{D_{ms}}{2}$	
Pitch circle diameter of gear C, dc	$\frac{m_n}{\cos\varphi}\times z_C$	
Efficiency of the Power screw		=((AM3*TAN(BK3)*BJ3/2)/BM3)*100
Tangential component on gear C	$\frac{2T_C}{d_C}$	=(2*CM3)/CN3
The radial component on gear C, F_r	$F_t\tan\phi_t$	=BQ3*((TAN(AE3*PI()/180))/(COS(AF3*PI()/180)))
Axial component on gear C, F_a	$F_t\times\tan\varphi$	=BQ3*TAN(AF3*PI()/180)
Toque on shaft BC	$T_D/2$	
Tangential force on gear B		=(2*(BM3/BG3))/(AB3-(AA3*(SIN(ATAN(Y3)))))
Radial force on gear B		=BT3*(TAN(AE3*PI()/180))*(COS(ATAN(Y3)))
Axial force on gear B		=BT3*TAN(AE3*PI()/180)*SIN(ATAN(Y3))
Shear load		=(AM3/2)/(((AT3))
Torsional load		=((AM3/2)*AU3*CQ3)/((8*50*50)+(8*50*50))
Resultant load		=SQRT((BW3^2)+(BX3^2)+(2*BW3*BX3*COS(ATAN((AW3/2)/(AV3/2)))))
Shear area		=PI()*(AQ3^2)/(1.28*4)
Shear Stress		=(BY3*AR3)/BZ3

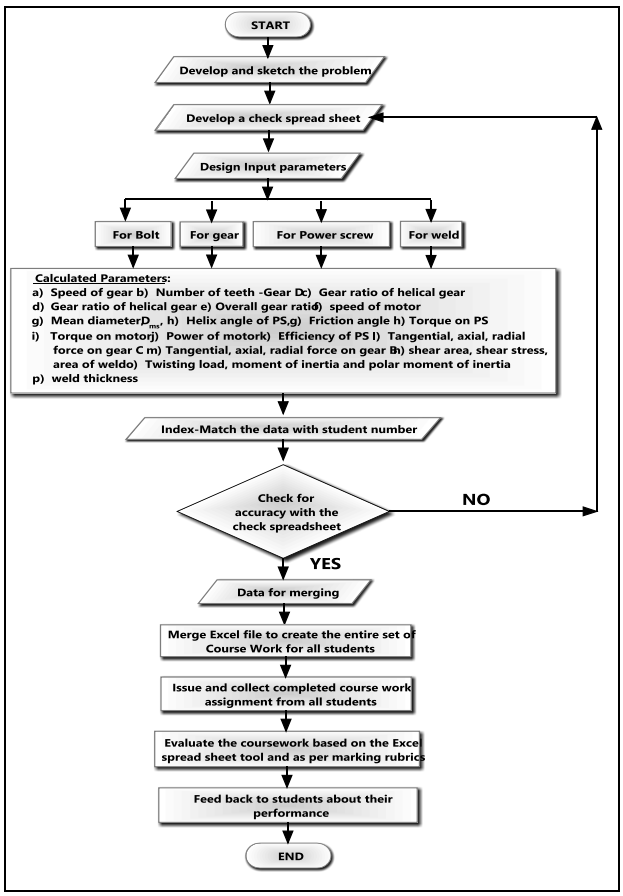

FIGURE 4 FLOW FOR DEVELOPING THE PACKAGE / EVALUATING THE ASSIGNMENTS

Further, the complete flow of the design process adopted in this spreadsheet is illustrated in Fig. 4 and it is very clear from this flow that each and every aspect of the design process is taken care meticulously. Also the final outcome of the student work is compared with solutions that are generated by the software package. Evaluation of the student work is very transparent and every student will be convinced of the marking process. Since evaluation activities are critical to effective development for students to further their knowledge and learning, providing timely feedback in terms of useful insights on the design ideas of students and the quality of their implementation will become very much essential.

V. IMPLEMENTATION, OUTCOMES AND DISCUSSION

Learning and teaching have become very demanding particularly in technical higher educational sectors and conduct of classes and assessment pose a greater challenge to teaching fraternity. Designing a course work paper involves a lot of time and energy in order to ensure that it meets prescribed learning outcomes of a particular module. On the other hand, advancements in Information and Technology have drastically changed the way education is provided and state of arts methods of delivery is very much appreciated and welcomed by students, particularly Y-Gen learners. Table III presents the generated output results pertaining to the input values fed by the tutor for a particular case. Based on the results obtained above, a CAD drawing (Fig. 5) is generated and displayed for tutors to countercheck the work submitted by each student. This will enable the tutors to quickly compare and assesse the work submitted by the students.

The present attempt brings out the efforts of teaching faculty at CCE to design an assessment paper with a range of unique data to each student and then to generate marking solutions for each student so that the accuracy and fairness are seen in the evaluation process. This kind of efforts is applicable to not only assessment/evaluation methods and it can be directed towards short courses including competency development, outsourcing, e-learning, and knowledge management systems.

The method developed partly automates the process though not in full. Although initial developmental stages of this package involves keying in a lot of data pertaining to the design problem and linking these unique data sets, it has got its own merits that result in a lot of advantages. Once a concrete shape in terms of generating the assessment papers and mark evaluation scheme is derived, it will then be very useful for tutors to complete the marking of the answer scripts.

Nevertheless, module tutors were instructed to do marking of some sample student assessment manually, based on the marking scheme and later do the marking based on the solution scheme generated by the package, and to compare their results, such as their time spent marking and the marks they awarded. Feedback received from module tutors

discovered that the majority of tutor results would have varied from the marking scheme.

Major coursework: Component Design – Gears

Given data:			Answers:		
Gear ratio A&B	2		Speed of PS	114	rpm
Nor. Module A	3	mm	Z_D	39.9976	teeth
Width	22.5	mm	G.R of helical gear	1.99988	
D_B	120	mm	Overall G.R	3.99976	
Z_C	20	teeth	Speed of motor	**455.972**	**rpm**
Nor. Module C	2	mm			
Pre. Angle (ϕ)	20	Deg.			
Helix angle (θ)	25	Deg.			
$a_{C\&D}$	66.2	mm			

Major coursework: Component Design – Power screw

Given data:			Answers:		
No. of start	2		Mean dia, D_{ms}	55	
pitch	10	mm	Helix angle of PS	0.11523	radian
D_{os}	60	mm	Friction angle	0.12927	radian
μ – Screw	0.13		Torque on PS	497393	N-mm
Velocity	0.038	m/sec	Torque on motor	124356	N-mm
Load	35000	N	Power of motor	**5937.91**	**W**
D_{oc}	100	mm	Efficiency	**22.3982**	**%**
D_{ic}	40	mm			
μ – Bearing	0.21				

Major coursework: Component Design – Weld design

Given data:			Answers:		
p_w	215	N/mm^2	Area of weld	600	mm
b	200	mm	Centroid X	67	mm
d	200	mm	Eccentricity	883	mm
Start of weld	750	mm	Shear load	29.1667	N/mm
Load factor	2		Ixx	4666700	mm^3
			Iyy	2666750	mm^3
			J	7333450	mm^3
			Twisting load	350.626	N/mm
			Resultant load	373.052	N/mm
			Weld Thickness	**2.5**	mm

TABLE III. GENERATAED OUTPUT RESULTS

Tutors marks also varied between tutors as there are discrepancies between tutors for the one task that needed a qualitative judgment from the tutors. This has reaffirmed that the developed package has got huge benefits to set assessment papers and make the student works quickly, accurately and consistently. The feedback indicated considerable savings in time from manually marking based on the key solution schemes to marking based on the solution schemes generated by the package developed. The overall results of this module reveal that there is an improvement in the consistency and accuracy of marking and the time of marking was reduced by an average of 53% i.e. approximately 16 hours of marking are saved for Mechanical Engineering Design module where the student size of 43. The time saved by each tutor through the automation process can be effectively used to enhance the technical strength of the assessment paper, increase the technical challenges in the question paper and also to provide constructive feedback to the students on their performance and means by which they can upgrade their deliverables.

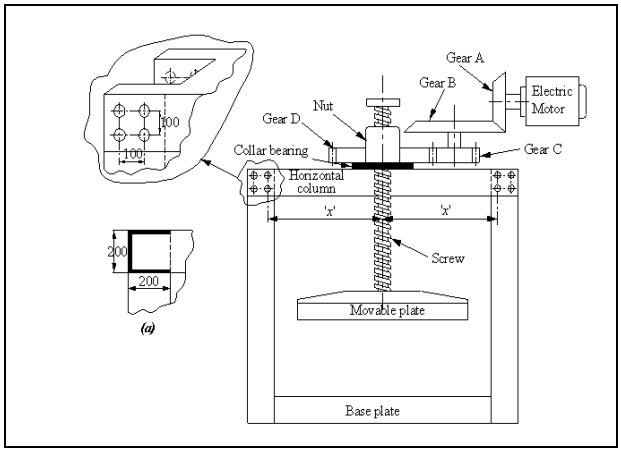

FIGURE 5 DESIGN DRAWING GENERATED

As a result of this application development, Caledonian College encourages green environment and eliminates printing of assessment papers for each student. The electronic copy of the paper was made available in the common learning system through the student can download the papers. The possible benefits achieved through this application of software package are listed down here.

- The package ensures that the standard and quality in marking, eliminating any bias while marking is done particularly, when the student numbers and module tutors are high.
- The package minimizes collusion, cheating and plagiarism by allowing all students equal opportunity to view the assessment solutions and marks obtained in order to discern high performers from normal performers demonstrating adequate variations of the actual performance. Deserving students are rewarded and individual efforts are marked proportionate to their efforts.
- It facilitates easy module administration of assessments in terms of paper generation and evaluation schemes to ensure consistent marking.
- It demonstrates to students the interest and motivation in their learning style with individualized question papers and evaluation.

VI. CONCLUSION

This present study describes the successful introduction, design, developmental activities for generating assessment papers and solution schemes for a particular module at the College. This is a novel technology that aims to enhance collaborative learning and assessment environment for young learners. The application developed focuses on design oriented tasks for an engineering module collaboratively and demonstrates to tutors and students on how the way the

learning and development of transferable skills can be enhanced significantly.

The motivation for this paper is the complexity being faced by the module team to generate assessment papers for large sized cohorts, particularly, for design based modules and eventually the marking of each individual answer paper. Students are expected to work on their own, with no reproduction of answers or collusion in any form whatsoever. This has prompted the team to think out of the box and create this package to make individual contributions clearer. Students and staffs will then realize, as a result of this package, a similar idea to develop computer based packages / portfolios with simple links between different resources. They can also embed a number of useful web objects such as graphics, audio and video clips in addition to text and web link.

The outcome and benefits of this package paves way for extending it to other modules in order to achieve many other benefits as demonstrated in this application. The package developed here can also be used for subsequent cohorts of students with suitable modifications in the expected tasks or in some situations may be a different component design altogether.

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