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A new approach of engineering higher education - the CIVA system

S H R Lo

School of Engineering Manchester Metropolitan University Manchester M1 5GD, UK

ABSTRACT

The CIVA system (standing for Coursework-driven teaching & learning process, Integrated teaching approach, Verification & Validation guided quality learning and professional development, and Active support mechanism) has been developed to address some key issues in the engineering education reform [1]. It represents a new way to manage the teaching and learning process in order to achieve a high quality engineering education outcome that is characterised by high academic standard, high inclusiveness and high employability. In this paper, a brief overview of the CIVA system and its rationale will be provided. This will be followed by the presentation of a CIVA coursework for a structural vibration module run in the 2016/7 academic session. This example shows that the CIVA coursework generates a problem-solving focused structured learning process that puts the learner in the driving seat throughout the process. Highlights of some new features in this session further demonstrate that the CIVA coursework, on one hand, is a powerful tool for integrating new knowledge and skills in learning and application, but on the other hand, may require extra efforts by the tutor to achieve the highly desirable individuality of the coursework for each student, especially for large sized classes. To set the focus for further development, the main challenges relating to each aspect of the CIVA system are identified and discussed. In conclusion, the CIVA system can bring about high pedagogical value for engineering education. For its further development, collaboration of universities with industry, software providers and testing equipment manufacturers is highly desirable.

Keywords: pedagogy for engineering education, CIVA system, inclusiveness, employability

1. INTRODUCTION

Engineering higher education (HE) plays a critical role in supporting and propelling technological innovation and advances that are one of the most striking features of the modern era. However, the severe skills gap as well as the shortage of well-qualified engineering graduates show that the current engineering education is not adequate in playing its role. Widening participation and internationalisation of HE have raised further challenges to achieving inclusiveness in engineering education [2][3][4]. In order to find solutions and modernise engineering education, an innovative approach for engineering education, the CIVA (standing for Coursework-driven teaching & learning process, Integrated teaching approach, Verification & Validation guided quality learning and professional development, and Active support mechanism) system has been developed. The CIVA system aims to address some key issues in engineering education reform and represents a new way to manage the teaching and learning process in order to achieve a high quality engineering education outcome that is characterised by high academic standard, high inclusiveness and high employability.

This paper first provides an overview of the CIVA system and explains from the pedagogy view point how essentially it addresses the four key elements of an effective teaching & learning process for engineering education.

It next presents a representative CIVA coursework for a structural vibration module that has been run in 2016/7 academic session. The main features of the coursework and the associated knowledge and skills required are explained. It demonstrates that the CIVA coursework generates a problem-solving focused structured learning process and a range of key skills for the discipline [5][6] can be incorporated into the process as in a real-world application scenario.

To set the focus for further development, the main challenges relating to each aspect of the CIVA system are identified and some initial recommendations are proposed.

It concludes that to achieve the full potential of the CIVA system for modernising engineering education, it would require that universities, industrial companies, engineering software providers and engineering teaching equipment manufacturers join forces to create representative CIVA coursework for different industries and different disciplines. Through further engineering education research, the methods and processes of generating CIVA coursework and the associated T&L package including the specifications of learner's current knowledge and skills level and the expected learning outcomes will be addressed.

2. OVERVIEW OF THE CIVA SYSTEM AND ITS RATIONALE

The CIVA system is an innovative teaching and learning method. The rationale behind the CIVA system is that for any effective learning to take place and for real value to be added to the learner, four key elements are essential including (1) motivation of the learner, (2) desirable value-adding contents, (3) built-in mechanism of self-assessment with further self-improvement and (4) relevant or customised learning support.

For modern engineering education, the CIVA system consists of (Refer to [1] for details):

(a) Coursework-driven teaching and learning (CDTL) process
(b) Integrated teaching approach (ITA)
(c) Verification and validation (V&V) guided quality learning and professional development, and
(d) Active support mechanism (ASM).

The CIVA scheme can be illustrated by a representative timeline and the associated set of teaching & learning activities for a structural vibration module as shown in Figure 1. This outlines how the CIVA system organises the teaching & learning process.

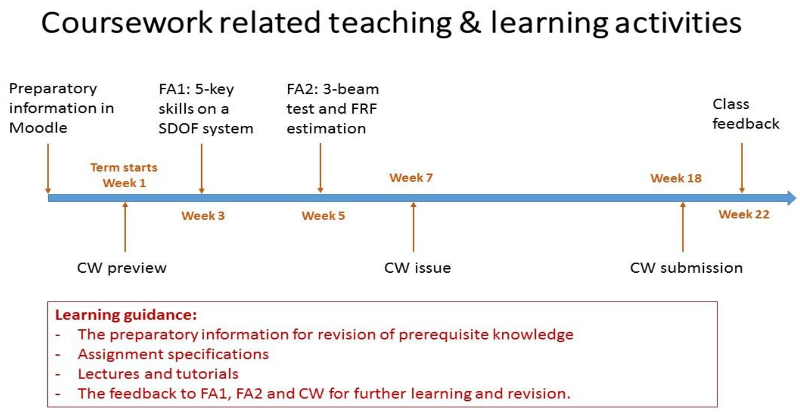

Figure 1 Structural vibration coursework-related T&L activities and the timeline

Furthermore, Figure 2 shows a schematic diagram of the structural vibration coursework. Further details of this coursework are presented in Table 1 of this paper.

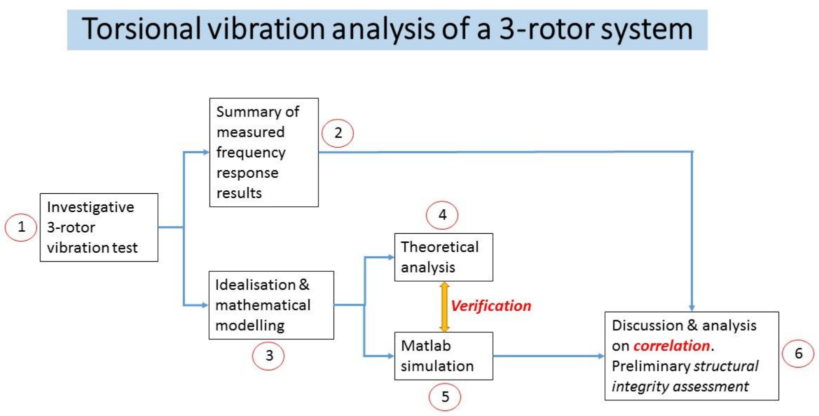

Figure 2 A schematic diagram of the structural vibration coursework

As it can be seen from Figure 1, the coursework is the central thread of the teaching and learning process. The summative nature of the CIVA coursework and its employability-enhancing features make students motivated in doing the coursework and engage with the supporting teaching and learning activities. The set problem and the guidance for the problem-solving approaches and processes help students develop understanding and thinking skills for planning as well as carrying out problem-solving activities. The integrated teaching provides students with a range of key knowledge and skills that professional engineers employ in industry. The verification and validation (V&V) processes help students develop critical thinking skills as well as the mentality, the attitude and the competence of problem-solving. The active support and the built-in flexibility in timing of the coursework adapt to the learning requirements of individuals or subgroups so produce better inclusiveness.

The potential benefits of the CIVA system to engineering education can be summarised as follows:

(a) To raise the employability status of the engineering course by making the curriculum adaptable to the requirements of the fast evolving engineering world.
(b) To improve the employability of the graduates by equipping them with the key knowledge, skills and experience of the relevant engineering sector.
(c) To develop in the graduates the mentality, attitude and ability of professional engineers in taking responsibility and working through complete problem-solving processes.
(d) To achieve inclusiveness in the global environment that the student intake is increasingly more diverse in multiple dimensions due to internationalisation and widening participation in higher education, etc..
(e) To make the teaching and learning effective for students to achieve a high level of attainment.
(f) To make the academic staff easier to carry out research-informed teaching.

3. AN EXAMPLE OF A CIVA COURSEWORK

With the CIVA system, the design of the coursework is of crucial importance. The aim is to generate a problem-solving focused structured learning process that incorporates the key skills for the particular discipline and is linked to the required learning outcomes of the unit syllabus.

The design of this structural vibration coursework requires the student to solve the problem of identifying the shaft with the shortest fatigue life under the specified loading condition by applying the five-key skills of vibration analysis, i.e., system idealisation, mathematical modelling, theoretical analysis, computer simulation and physical testing, to the three-rotor system shown in Figure 3.

The main features and the associated knowledge and skills of this coursework are summarised in Table 1. Those required knowledge and skills in the last column have either been developed in this module through a range of T&L activities as well as self-study or were already covered in the previous study so revision and application to new scenarios were the requirements. To clarify the correspondence between Figure 2 and Table 1,the ringed numbers in Figure 2 are indicated in the first column of Table 1.

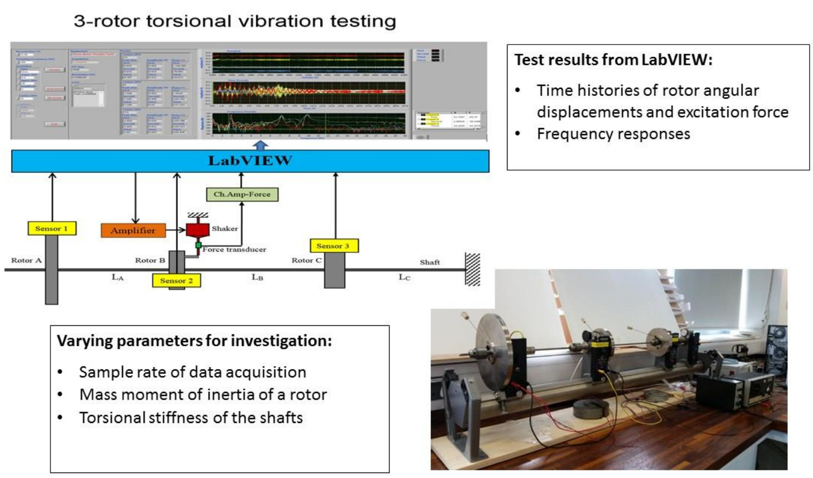

Figure 3 Setup of the investigative lab of the 3-rotor torsional vibration system

Table 1: Summary of the structural vibration coursework

Item	Coursework features	Knowledge/skills applied
P1	Investigative vibration tests of the 3-rotor system to measure time domain and frequency domain responses	Vibration testing method, instrument and transducers, and data acquisition
P2	Examination of acquired data to extract dynamic properties	Data processing, feature extraction, and dealing with uncertainties
P3	(i) Idealisation of a physical system, by making assumptions based on lab observations and provided information. (ii) Derivation of equations of motion	(i) Idealisation of physical system into analytical model. (ii) Mathematical modelling for theoretical solution and computer simulation.
P4	Theoretical analysis – manual solutions (modal analysis and forced response calculation for sinusoidal input)	Application of analytical skills. Closed-form solution for simple excitation.
P5	(i) Computer simulation (MATLAB) of the same scenario as in P4 with verification by manual solution. (ii) Computer simulation of forced response using the verified computer program with more complex input (e.g., swept sine input) (iii) Determination of Frequency Response Function (FRF) using the simulated input/output signals. British Standards on digital signal processing are applied. (iv) Correlation of the resonant frequencies in the simulated FRF to the system natural frequencies determined in P5 and P6 to check the reliability of the estimated FRF and the damping effect. (v) Virtual investigation of the effects of parameter variations in the same way as in the physical tests	(i) Verification of the computer programs by manual solution for simple excitation. (ii) Virtual testing of the system behaviour using the verified computer program. (iii) Application of digital signal processing techniques to virtual data. Working with relevant industry standards. (iv) Verification of the simulation results in the frequency domain. (v) Imitating the physical tests by virtual tests in terms of parameter variations
P6	(i) Comparison of changes in peak frequencies between the simulated results and the test results in a qualitative manner. (ii) Relating the calculated vibration responses to the stresses caused in each shaft and carrying out preliminary	(i) Correlation of virtual test results with physical test results in a designed way (ii) Understanding of the relationship between vibration responses and fatigue life of structural components

	structural integrity assessment for fatigue failure	

Highlights of some new features in the 2016/7 session include

(a) British Standards on digital signal processing for vibration testing are introduced and applied in conducting experimental testing and processing the measured data (P1) and in processing the simulated input/output signals to estimate the frequency response function (P5(iii)) of the system. This way of introducing the British Standards is effective as the students are already motivated by the application in the coursework and also can experiment virtually with different scenarios using the computer model to gain a better understanding of the theories involved.

(b) Keeping the individuality of the coursework for each student has been considered to be a priority for the CIVA coursework, mainly for achieving fairness in the assessment. This has posed a significant challenge in the situation that the ratio of the number of students to the number of test rigs is large, around 60 in this case. To overcome this difficulty, a new way of correlating the experimental data with the analytical results has been devised. Essentially, based on the vibration theory, designed changes in mass and stiffness distributions are made during physical tests and then comparable changes in these parameters are introduced in the computer simulation runs. The correlation is then carried out between the changes of the dynamic properties of interest in a qualitative manner. Although this qualitative correlation may only serve as a basic level of validation for professional engineering work, it is still highly valuable for the learning process. However, this has also illustrated the challenge that many engineering courses face, that is, how to maintain the individuality of physical test-based coursework for large sized classes.

4. MAIN CHALLENGES RELATING TO IMPLEMENTATION OF THE CIVA SYSTEM

To set the focus for further development, the main challenges relating to each aspect of the CIVA system have been identified and some corresponding initial solutions are recommended as follows (see the Overview section for the abbreviations):

CDTL – design of the coursework contents to generate a problem-solving focused structured learning process and the corresponding T&L package for the particular discipline. Selection of the problem to be solved and acquisition of the associated information.

Recommendation: Collaboration between academic staff and industry would be highly desirable.

ITA – organisation of the T&L activities and access to the T&L resources that cover multiple knowledge and skills areas to implement a T&L program that builds a coherent structure of the disciplinary knowledge and skills. Tutors who can teach multiple knowledge and skills covered in the CIVA coursework.

Recommendation: In addition to the main tutor running the coursework, a network of specialist tutors in different aspects possessing specialist technical learning resources that are relevant to the discipline of the specific CIVA coursework should collaborate to provide supports to ensure the quality and efficiency of the provision.

V&V – suitable teaching test rigs with wide-ranging adjustable physical parameters so that individual setup can be achieved for each student in practice with large groups.

Recommendation: Collaboration with teaching test rig manufacturers would be required.

ASM – design and implementation of a smart and effective learner support system as this is the key to achieve inclusiveness and promote self-learning.

Recommendation: This support system may consist of two facets. One is a pre-defined learning plan that maps the status of the prior learning of the individual learner to the common end target of the CIVA coursework. The other is the smart interventions to add extra support for some discrete topics during the coursework process.

Finally, it is considered that an end examination under controlled conditions for the topics involved in the CIVA coursework is highly important as it is not only an assessment of the learning attainment but also an effective motivator for serious learning while doing the coursework. Furthermore, exam questions at a higher technical level and with more open-ended challenges can be set with justification because some in-depth learning as well as the experience of application have helped the learner gain a better understanding of those topics.

5. CONCLUSION

It can be concluded that the CIVA system represents an attempt to address the four key elements of an effective teaching & learning process including (1) motivation of the learner, (2) desirable value-adding contents, (3) built-in mechanism of self-assessment with further self-improvement and (4) relevant or customised learning support. Success in addressing these four key elements is the fundamental reason why the CIVA system is effective in motivating, guiding, training and supporting students in their learning process.

The CIVA coursework generates a problem-solving focused structured learning process as demonstrated by the structural vibration coursework. Combining problem-solving and structured learning makes the CIVA coursework an effective and efficient way of learning.

The 'built-in mechanism of self-assessment with further self-improvement' has been achieved in the CIVA coursework in the form of Verification & Validation. It has been observed that this generates a particularly effective learning gain and therefore from the pedagogy view point, it is highly valuable.

Finally, it has highlighted that to generate effective CIVA coursework, collaboration of universities with industry, software providers and testing equipment manufacturers is highly desirable and this will bring about one of the most beneficial outcomes for the engineering education reform.

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AUTHOR

Sophie Hong Rui Lo graduated from Tsinghua University in China with BSc in Solid Mechanics and obtained PhD from ISVR in Southampton University in characterisation and identification of non-linear systems. Sophie Lo is a senior lecturer in School of Engineering at Manchester Metropolitan University. With research and teaching experiences in computer aided fatigue analysis covering structural dynamics, stress analysis, fatigue analysis and digital signal processing as well as the CAE counterpart of these topic areas, her current interests are in engineering education in both the technical discipline as well as the pedagogy in order to meet the challenges and requirements of the contemporary society.