Examples of Authentic Assessments in Engineering Education

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Abstract— Paper-based assessment in engineering education is a widely accepted way of assessing student learning. This type of assessment typically involves answers to discipline specific problems, that may require some use of equations, methods and concepts, and short or long answer to theoretical questions that require a deep conceptual understanding of the topic. It has been reported that assessments that are practice-oriented and have similarities with real-world situations and context, benefits student learning. Such real-world problems are generally termed as “authentic”. While some disciplines may have difficulties in designing assessments that are practically relevant, the engineering discipline has little problems in handing out high fidelity assessments. This is since engineering curricula worldwide is carefully designed to meet industry demands i.e. create work-ready graduates (WRG). Along with this, the undergraduate engineering program operates within a shorter time frame (usually 3-5 years). Hence, in engineering, most problems are practice oriented. It appears that real-world relevance is only one of the key criteria required when designing authentic assessments and there is an overall misunderstanding of what constitutes an authentic assessment and how to efficiently prepare them. In a rapidly changing higher education sector, an added dimension to authentic assessments is that they must be safeguarded against widespread contract cheating. This paper discusses the essential components of an authentic assessment and provides several examples of such assessments, suitable for undergraduate civil engineering students. More traditional assessments are discussed with developed authentic assessments. Built-in contract cheating safeguarding mechanisms are discussed in some detail.

Keywords— *authentic assessment, contract cheating, higher education, civil engineering education, integrity in higher education*

I. INTRODUCTION

Student assessment of acquired or gained knowledge through evaluation of written assessments is a regular task of an academic. It has been long understood that assessments must be realistic i.e. be of similar kind of what a student will experience and must deal with in the real-world [1]. Such high-fidelity assessments have been generally referred to as “authentic” (see [2, 3]). Reference [4] defined authentic assessment as developing the same cognitive abilities that the student will need, after graduation in a real-life situation. Reference [5] discuss that authentic assessments are tasks that are inherently meaningful, are interesting and have long-lasting values. The perception of what constitutes an authentic assessment is varied and different researchers have stressed on different factors and criteria when designing such assessments. Reference [3] suggested a five-dimensional framework for authentic assessments. In their view; task, physical and social context, results and criteria on which

students will be judged are important considerations. Reference [2] suggested that eight critical elements are necessary when designing authentic assessments: challenge, performance or product (outcome), transfer of knowledge, metacognition, accuracy, fidelity, discussion and collaboration.

II. AN ADDED DIMENSION TO AUTHENTICITY: CONTRACT CHEATING

The term contract cheating generally refers to the situation where students outsource their assignments to external third parties and later submit this assignment for grading under the pretence of being the student’s own work [5]. It is generally agreed that such contract cheating activities are on the rise and poses a significant threat to higher education worldwide ([7, 8]). Unfortunately, contract cheating, if takes place, can be very difficult to detect [9]. It is therefore important that assessments are designed with inherent mechanisms that are embedded within the assessment, such that even if such assessments are outsourced are unlikely to get solved through contract cheating. If assessments are designed with such mechanisms using discipline specific knowledge with built-in complexity, a high probability exists that solutions of such assessments will be difficult to obtain through means of contract cheating. This perception is true considering a range of aspects; firstly, although contract cheaters claim to be subject matter experts, research suggests that so called experts take on assignments on various subjects. Secondly, introducing adequate complexity by relating related concepts together in one problem increases the difficulty level of the problem. This makes it hard to solve the problem without following lecture materials and classroom instructions, hence online tutors are unlikely to take on such assessments due to a high time commitment, in turn making the assessment expensive for a student to purchase. It needs to be acknowledged that the cost of an assignment is not the prime deterrent. Reference [10] investigated the reasons student contract cheat. Their findings suggest a lack of perseverance as the primary reason why students contract cheat. A holistic approach to assessment design is therefore required, where students are inherently motivated to solve problems themselves.

In a large survey conducted in Australia (see [17]) exploring the relationship of assignment types and contract cheating found that four types of assignments (out of total thirteen different types) are least likely to be outsourced by students to third parties for solutions; i) assignments that are unique and personalised, ii) in-class tasks, iii) viva and iv) reflection on practicum. The number of student participants was 14,086. The same survey also asked

educators how likely they use different types of assessments in their teaching. A total of 1147 educators participated in the survey. The results indicated that less than 30% of educators use the above four assessment types that safeguard against contract cheating. It is therefore important that discussion takes place on how assessments can be designed such that they are unique, personalised, promote active student participation and create sustained interest. Such a design approach must also be easy to implement so that educators who are not necessarily education researchers but often need to teach at a tertiary level can easily follow and implement. To this effect, the CPACS (contextualization, personalization, authenticity, complexity and storytelling) assessment design method was recently presented ([11]) embedded within the framework of AfL (Assessment for Learning, see [5]). Unlike previous research on authentic assessments, an added dimension to assessment design must be that of preventing contract cheating and this idea of prevention is central to CPACS. This paper presents three examples of CPACS and discusses the way key assessment ingredients can be introduced to more traditional assessments, which is hoped to guide academics involved in assessment preparation in preparing their own assessment questions.

III. EXAMPLES OF AUTHENTIC ASSESSMENT QUESTIONS

A. Mohr-circle

Mohr-circles are widely used in civil/mechanical engineering as a tool to help students graphically visualise the stress states within a two-dimensional deformable body [12]. Excluding use of software, there are two approaches by which any Mohr-circle problem can be analytically solved; i) the first is the equation approach, where equations based on equilibrium are used to calculate stresses (or strains) on the desired plane and ii) second is the graphical approach, where a scaled drawing, typically on a graph paper is used to find stresses and strains on any desired plane. As the main goal is to be able to visualise the stresses or strains, the latter approach is preferred with results obtained can be verified through equations.

One key underlying essence that is often missed in explaining and teaching Mohr-circles is: why is it that the stresses change with altering exploratory planes (planes that cut through the deforming body or object)? In fact, this is the fundamental reason why Mohr-circles are needed in the first place. This discussion is covered in books and courses that introduce Mohr-circle, typically with book titles; Strength of Materials [12] or Mechanics of Materials [13]. In most institutions, Strength or Mechanics of Materials are taught in the early years (first or second year of an undergraduate program). In discipline specific engineering courses, for instance in civil-geotechnical engineering, the concepts of Mohr-circles are used in both introductory and advanced geotechnical engineering courses. Hence, Mechanics of Materials is generally listed as a prerequisite subject, where depending on the time gap, students may forget key principles of Mohr-circle and a refresher is generally needed. Therefore, most geotechnical engineering books do not discuss the key essence of Mohr-circles as discussed above but rather focus more on problem-solving

(see [14]). This generates students who are great problem solvers but fail to realise the essence of the problem they are solving, particularly why the stresses are different in the first place, hence the need for Mohr-circles. An important question to ask in assessing student understanding of Mohr-circle would then be as follows: discuss technically with the help of a figure why do stresses change with altering planes in context to Mohr-circles? Depending on the subject (structural engineering or soil mechanics), this part of the question can be easily tied to problem-based traditional questions [12-14]. Hence, the question may judge both the conceptual understanding of Mohr-circles as well as problem-solving capabilities of students.

Fig. 1 Foundation with two-way loading

B. Foundation with two-way loading

You are working as a geotechnical engineer in a reputed construction firm based in Porto, Portugal. For a large commercial reinforced concrete building, a column foundation needs to be designed. The square column has dimensions of 0.3 m X 0.3 m in cross-section with a length of 10 m. Your manager Ricardo, from his experience, suggests that a 2 m X 2m square footing will be sufficient in supporting the column loads (Fig. 1).

The base of the footing is located at 1.8 m from the ground surface and the water table is sufficiently far from the base. The soil friction angle and cohesion were measured in triaxial tests as $\phi = 35$ degrees and $c = 10$ kPa, respectively. The soil unit weight was measured as 17 kN/m³. Determine with due account to eccentricity and horizontal loads whether the foundation Ricardo suggested is adequate or not? Considering sliding resistance, use the methods of Hansen and Meyerhof with reduction factor R_e for the bearing capacity calculations. Assume the exponent parameters to be $\alpha_1 = \alpha_2 = 3$. If the foundation is not adequate, propose alternate safe dimensions with your calculations. Comment on your results. Remember to include both directional calculations. If the footing base is tilted by a positive 20° , what will be the ultimate bearing capacity in the B direction according to the method of

Hansen? Compare with the case with no tilt above and comment on your results.

C. Pipe pressure hydraulics

Fig. 2 Drainage pipe blockage (modified after [14])

Textbook problems that are usually found at the end of a chapter do not often add enough context to the problem. This is because the context is discussed prior to presenting the problem and apparently it is safe to assume the reader will read and understand the textual explanation before reading the problem. However, in a paper-based assessment, where a series of questions are usually required to solve, the context is often missing and adding some more details enriches the question and helps in clarifying the significance of the problem. This is a classic example where out of context textbook solutions (see [14] for the original question) can be modified and improved through added context and personalization with very little effort.

A huge storm has taken over Porto and several drainage pipe blockages around the city have been reported by citizens of the Porto region. In Fig. 2 above, the pipe has been completely blocked by a plug of sand 1.5 m long, followed by another plug of a mixture of sands, silts and clay 0.5 m long. When the storm was finally over, the water level above the ground was 1 m. The permeability of the sand is twice that of the mixture of sands, silts and clays. The council suspects that if the water pressure within the old drainage pipe is too high, the pipe may burst. You have been assigned to calculate the following:

- find the pore water pressure at the centre of the sand plug and at the centre of the mixture.
- find the average hydraulic gradients in the sand and mixture. These average hydraulic gradients can be used to check against seepage instability by comparing it to the critical hydraulic gradients respectively. Hint (select a datum at the centre line of the pipe and find heads at A and B. Use the principle of continuity i.e. the flow rate of water through the sand and mixture must be the same).

IV. DISCUSSION

The concept of Mohr-Circles in two-dimensional stress and strain analysis is widely used in many engineering

disciplines. Unfortunately, the essence of the Mohr-Circle is not well understood by many students, although students are generally able to solve a diverse range of Mohr-Circle problems available in numerous textbooks (see for instance [14]). The reason for not grasping the essence of Mohr-Circles is because the concept is not explained intuitively in textbooks discussing Mohr-Circles. Focus is more on problem-solving and equations resulting from Mohr-Circles, as opposed to understanding the essence and true significance of Mohr-Circles. An exception to above is the elegant explanation of [12]. Fig. 3 explains the fundamental reason why Mohr-Circles are required.

Assuming a two-dimensional body is subjected to the forces P_1 , P_2 , P_3 and P_4 . It is of interest to determine the internal stresses within the body at an element as shown with a box in Figure 3(a). An exploratory section must then be passed through the element so that the internal forces on the element can be explored. Initially, a choice of an exploratory section a-a is made as shown in Fig. 3(a). Fig. 3(b) shows the equilibrium of the cut portion. If the resultant of force P_1 and P_2 is R , then collinear to R , force E must act on section a-a for equilibrium. Section a-a is deliberately chosen such that E is perpendicular to the cut section, hence only produces a normal stress σ on the element. The element is not subjected to any shear stresses (τ) in this instance and therefore by definition a-a must be a principal plane (principal planes are planes with no shear stresses).

Fig. 3(c) shows another possible section b-b. In this instance, the element must be subjected to both shear and normal stresses as force E has both normal and shear components (N and T , respectively). This suggests the mind-blowing fact that the stresses at an element located inside a body are not independent but dependent on the choice of the plane the analyst makes (a-a or b-b in this case). An intriguing question is then why section a-a or b-b has been chosen and not any other sections? There is indeed an infinite possibility and any arbitrary section through the element could have been chosen. This is where the concept of Mohr-Circle comes in, where German Civil Engineer Christian Otto Mohr (8 October 1835 – 2 October 1918) came up with his intuitive idea that all the possible planes can be represented by a circle, where each point on the perimeter of the circle represents a stress state (combination of normal and shear stress). As there is an infinite number of points on the perimeter of a circle, the infinite possible planes are accounted for.

Fig. 3 Understanding Mohr-circles

The second example is a foundation design problem with adequate complexity. As discussed before, complexity is a necessary ingredient of authentic assessments and such task prepares students for real-world engineering problems that are often very challenging [2]. The question starts by

setting up the context and work environment of the problem. Such contextualization helps the student to be at the right frame of mind and creates a real-world scenario that he or she will eventually experience. Contextualization also aids in understanding the importance of the problem and increases situational interest [15, 16], which in turn may trigger a sense of belonging to the engineering profession and therefore motivating students in solving the problem on their own, rather than outsourcing them to third parties. Personalization is added to the problem by naming a location of the project (use of proper nouns) and exploring the team-relationship.

As opposed to directly providing the soil material parameters, these are linked to laboratory triaxial tests. This is to reinforce the importance of laboratory tests of soils to find required design parameters, a practice routine in civil-geotechnical engineering but often taught in isolation. The column is subjected to lateral loads, which makes the solution sufficiently complex as moments about two axes are generated that must be supported by the foundation. Two different methods are requested (Hansen and Meyerhof) so a comparative analysis can be performed. Additional complexity is added by considering foundation tilt. The solution to this problem is long (approximately ten A4 pages when handwritten). Such complex and long problems are unlikely to be satisfactorily solved by third party contract cheating service providers. Even solved the solution is likely to be expensive, hence works as a deterrent.

The final problem is adapted from [14], where a drainage pipe blockage situation is analysed after a storm has hit the Porto region. Additional context is added by incorporating a governmental body (the council), responsible for maintaining drainage pipes. The importance of calculating water pressure is added by adding the fact that these pipes are old and excessive pressure may damage the pipe. A hint to the solution is included directing students to the appropriate engineering principles needed. The corresponding more traditional form of the same question can be found in [14].

V. CONCLUSION

So far in the literature authentic assessments has been thought separate to contract cheating, where providing real-life high-fidelity assessments were the main goal and whether assessments are outsourced or not were not of concern [3]. Higher education has changed dramatically since the advent of the internet and online contract cheating activities are on the rise. A survey conducted at Australian universities, exploring the relationship between contract cheating and assessment design found that assessments that are personalised and unique, in-class tasks, viva, reflection on practicum are least likely to get outsourced [17]. Unfortunately, the same study showed that very few academics (less than 30%) use assessments which are known to safeguard against contract cheating.

The paper demonstrated that how the key ingredients of an authentic assessment can be practically implemented through modification of existing traditional questions using CPACS (context, personalisation, authenticity, complexity, storytelling or reflection) assessment design method. Three examples were provided related to civil construction and geotechnical engineering but principles discussed can be

utilised for other engineering disciplines. Future work in this space should test student perception of these improved assessment questions as well as examine solutions provided for these questions by various contract cheating agencies.

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