ENHANCING SUSTAINABLE ENGINEERING EDUCATION WITH CODESIGN AND SCRIPT CONCORDANCE: A WORK IN PROGRESS

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Abstract – *This paper introduces a new approach to engineering education that integrates script concordance and codesign principles in a sustainable production course. The engineer's role constantly evolves amid the uncertainty of dynamic challenges, necessitating the development of reasoning skills during their education. Script concordance assesses clinical reasoning skills under uncertainty, while codesign is a participatory method involving stakeholders in the design process. A collaborative team of students (bachelor and master), lecturers, professors, and pedagogical experts to design script concordance scenarios in a sustainable development context. We conducted several workshops to co-create and validate the scenarios, which covered topics such as multidisciplinary, multi-criteria analysis, multidimensional reasoning, and ontology. The desired results are for students to be able to describe their reasoning plausibly and to justify it in problems where no precise answers enable causal relationships. This will bridge the gap between theory and practice that employers may observe in the field of engineering.*

Keywords: Script concordance, codesign, innovative pedagogy, engineering education.

1. INTRODUCTION

Engineering constantly evolves and faces new challenges, the engineer's role adapts to the uncertain environment, requiring the development of reasoning skills during education to prepare for real-world scenarios. Script theory suggests that within long-term memory, there exist sets of knowledge referred to as scripts. These scripts empower individuals to interpret data within situations, facilitating the progression of understanding and problem-resolution [1]. Developed by Bernard Charlin, script concordance methodology emerges as an instrument to evaluate clinical reasoning skills in the context of uncertainty, whereas codesign is a collaborative approach to engaging stakeholders actively in the design process [2]. Script theory involves simulated scenarios where students make micro-judgments and compare them to expert responses. Those innovative approaches in engineering education are vital for experimental teaching and learning. Its goal is to enable students to articulate their reasoning plausibly and justify it in scenarios with ambiguous solutions, fostering critical thinking and preparedness for real-world challenges. The motivation behind this study lies in recognizing the growing challenges in an ever-changing world. Faced with this reality, it is imperative to develop reasoning skills among engineering students early in their education. Integrating script concordance and codesign into a sustainable production course aims to prepare students to respond to its role to adapt to the uncertain environment by enabling them to articulate their reasoning in complex and ambiguous real-world situations.

This study aims to utilize script concordance, assessing clinical reasoning skills under uncertainty, and codesign, a participatory method involving stakeholders in design. This paper explains the methodology used, describes the teamwork involved, and provides examples (vignettes) of the script concordance scenarios that were created by this repeated and participatory method. For the creation of these vignettes, we implemented two approaches. First, in the context of sustainable development, we formed a collaborative team consisting of students (both bachelor and master levels), lecturers, professors, and pedagogical experts. Second, we also proceeded in the context of courses on forming and assembly processes for the creation of specific vignettes. Vignettes were created by a professor and subsequently discussed with lab supervisors. These vignettes were then presented to students, who generated eco-conception designs based on the described challenges. Subsequently, these designs will undergo evaluation by experts to assess their viability and applicability.

The rest of the paper is organized as follows: section 2 presents a brief literature review of the script concordance, and codesign in section 3. Section 4 presents the results of the workshops we conducted with the integrated methodology in the context of sustainability in the industrial engineering fields with a few examples of vignettes.

2. SCRIPT CONCORDANCE

Script concordance is a cognitive learning methodology used in the medical field. Introduced in the 1990s by Dr. Bernard Charlin and colleagues at the University of Montreal, it aimed to provide a way to measure the clinical reasoning of medical students and healthcare professionals in complex and ambiguous diagnostic situations [1]. Thus, clinical reasoning is a multidimensional cognitive process crucial for assessing and managing a patient's condition [3]. Clinical reasoning is an intangible medical process and is challenging to comprehend due to its invisible, dynamic, and poorly understood way of thinking [3].

Script concordance enables students to progress toward mastering a task with initial guidance from the instructor. This process permits students to assess medical reasoning under uncertainty. It resembles scaffolding but gradually disappears as students' confidence increases. Therefore, candidates in script concordance are provided with concise clinical scenarios to consider before answering a series of questions designed to elicit opinions of potential diagnosis or management options as new elements of information are provided. While sufficient clinical context is provided to enable meaningful decisions, each case deliberately embeds uncertainty. Learners compare their answers with a reference panel, assessing the quality of their reasoning. Panel members explain their answers, providing insight and validating student's developing reasoning, or offering corrective feedback when needed. This allows students to understand the degree of concordance between their answers and reasoning [4, 5].

Script concordance primarily serves to refine the diagnosis of a given situation. Initially, one would make a preliminary assessment. Additional information is then provided, refining, and narrowing the focus of the reflection towards fewer choices that are, however, more substantiated. Subsequently, in a medical context, this is compared to the choices made by experienced practitioners. In our case, this constraint presents an opportunity to generate a solution that aligns with the initial requirements.

The learning script concordance (LSC) methodology stands out in two ways: firstly, by employing an interactive format using questions that mimic the way clinicians analyze data once hypotheses are activated. Secondly, by allowing participants to assess the alignment of their answers with those of a reference panel. The combination of specific, time-phased knowledge about a given illness provides a strong means for developing appropriate illness scripts. In this way, the methodology helps develop the reasoning skills needed in complex environments with changing information, such as engineering [4]. Charlin and al. [1] also designed a guideline step by step for LSC to enhance professional reasoning skills. They identify six key variables for the design of an effective LSC tool: pedagogical goals, nature of the task, content and level of complexity, reference panel, feedback, and digital learning environment. Their study's findings underscore the versatility of LSC across various professions, highlighting its adaptability and efficacity in diverse educational settings. However, within our context, the socio-constructivist perspective seems to be more pronounced in this study. We focus on organizing presentations where students showcase solutions to their peers, fostering collaborative learning and social construction knowledge. In contrast, Charlin's team, predominantly engaged in computer-based activities for interaction. This method might not foster a robust social construction of knowledge. Nevertheless, both approaches contribute valuable insights into the application and evolution of LSC methodology in professional education.

Script concordance theory is a valuable tool for educators seeking to integrate this approach into their teaching practices to achieve effective learning outcomes [2]. Choosing a socio-constructivist approach in engineering enables active and collaborative learning, where students construct their understanding through social interactions. It promotes better knowledge retention and social awareness, preparing students to become more responsible and competent engineers with a focus on sustainability. Since industrial engineering problems must be solved in a complex, multidisciplinary, and multisystem context, students must be trained to exercise professional judgment in a dynamic environment. By integrating codesign and script concordance, it is possible to help students develop these reasoning skills.

Selecting SC for designing a sustainable curriculum offers several advantages. SC allows students to navigate multidisciplinary, uncertain, and complex scenarios commonly encountered in real-world sustainability challenges. By presenting brief clinical scenarios followed by questions that solicit judgments about sustainable development possibilities or decision-making options, SC enables students to develop critical thinking and problem-solving skills specific to sustainability issues. This method deliberately embeds uncertainty and ambiguity, mimicking the conditions faced in authentic sustainability contexts. This approach fosters deep learning by encouraging students to grapple with real-world complexities, preparing them to address sustainability challenges effectively in their future engineering careers.

In Table 1, we have compared four studies of the LSC; we wanted the pedagogical team's point of view and the student's point of view. The gaps found in the readings are that there is no questioning of the experts' cognitive biases regarding certain practices and situations. Almost all studies are carried out in medicine, pharmacology, dentistry, and other healthcare fields. The four studies vary in terms of the composition and preparation of the teaching team, the type of validation process used, the level and preparation of the students, the perspective and tool used for assessment, and the overall pedagogical objectives. The

first study focuses on comparing the performance of individual and team-based SC testing. It involves a pedagogical team of experts in the field and focuses on the content validity and reliability of results. Study 2, on the other hand, conducts a multicenter comparative study, involving a larger group of hospital-based internal medicine physicians. This study evaluates the viability of SC tests. Ontology refers to a structured representation of knowledge. Study 3 innovatively integrates ontologies to enhance the usability of SC testing by providing a structured framework for organizing knowledge, improving assessment content, and facilitating item generation. In this context, the structured representation of knowledge provided by ontologies not only improves the usability of SC testing by organizing information and facilitating item generation but also aligns with pedagogical objectives aimed at enhancing the effectiveness of the methodology. Pre-clinical students are targeted. Lastly, study 4 is a comprehensive guide that describes the fundamentals and principles of SC testing construction. While each study provides valuable insights, they collectively underscore the versatility and complexity of implementing SC tests in educational settings. These settings respond to diverse pedagogical objectives and student populations.

3. CODESIGN APPROACH

Codesign is a participatory approach involving the active engagement of various stakeholders in the design process. In the field of education, codesign is often employed to develop curricula, educational tools, and other educational products in collaboration with teachers, students, and other stakeholders. [6] [7]

Dodero et al. [6] have summarized codesign methods as expanded participatory design, encouraging collaboration between users and designers to understand products from a variety of viewpoints. Codesign approach is used to bring diverse knowledge by involving different stakeholders [7]. By giving the team equal power, codesign enables the team to share responsibility for different aspects of project design [8]. Based on this information, in a professional setting, it facilitates stakeholder involvement in product, service, or process design. It ensures solutions meet the needs of users and those who will manufacture or manufacture them, maintain or even be in charge of their end-of-life. Codesign methods attract teams and companies, particularly in the healthcare system. Nevertheless, they can also be difficult to implement and manage, taking longer time to execute than traditional research approaches partly due to the vague definition of codesign [7]. Clear guidelines are essential for successful implementation [6]. For this reason, our method integrating codesign and script concordance will be established precisely, as clarity is necessary.

Applying codesign in pedagogy involves engaging students, teachers, and stakeholders in curriculum, fostering active, collaborative learning tailored to learner needs. In learning environments such as universities, students and teachers play different roles. Many different challenges need to be addressed, such as evaluating the benefits of learning, designing engaging activities, clarifying the roles of teachers, and organizing effective group collaboration. Codesign improves learning outcomes and quality. It reshapes the dynamics between educators and learners and promotes the professional growth of teachers. These are the key results of this participatory process. However, although codesign has been shown to improve learning outcomes and quality, its widespread adoption is limited by the absence of detailed references on how to implement these practices. In other words, while there is evidence that codesign is effective, many educators may struggle to implement it because they lack clear guidance or references on how to do so effectively. Time can impact the codesign process and it is a key factor that can influence its outcomes [9]. Essentially, it suggests that the amount of time allocated to codesign activities can affect the outcomes. For example, more time devoted to codesign may lead to more thorough planning, better collaboration between educators and learners, and ultimately, more successful implementation of the designed educational interventions.

Iniesto et al. [7] reviewed 32 papers on codesign in health education. They observed that stakeholders are involved in different stages such as brainstorming, reflection activities, feedback, and so forth. The authors also observed that processes tested using codesign methods are generally improved through the involvement of different stakeholders. These bring different knowledge and insights [7]. Garcia's study [9] aims to develop authentic learning scenarios in higher education through codesign involving students and teachers. This study explores the roles, stages, and effects of codesign. Participants came from blended online and face-to-face classes (University of Barcelona) and virtual universities (Open University of Catalonia) across a wide range of disciplines. Results showed the effectiveness of codesign in developing tailored scenarios, with students and teachers continuing to refine by adjusting to enhance quality, promoting deeper learning and autonomy. The study highlights the value of collaborative approaches for improved learning outcomes in higher education.

In the next section, we present vignettes from the workshop that integrate the codesign and script concordance approaches.

Table 1 Comparison of Concordance Studies

Title of the study		"Teaching by concordance: Individual versus team-based performance" [10]	"Are script concordance tests suitable for the assessment of undergraduate students? A multicenter comparative study " [11]	"An Ontology-Driven Learning Assessment Using the Script Concordance Test" [12]	"Script concordance testing: From theory to practice: AMEE Guide No. 75" [5]
Pedagogic Team					
Vignettes Prepa-ration	Vignettes	20 cases & 57 questions	20 cases & 62 questions Written by one expert	• Automated question generation. • Direct and indirect strategies for Likert-type scale scoring.	25 cases & 75 questions Written by two experts familiar with the purpose, target audience, and content domain.
	Students	Review the course objective and material for 5 days	Study for exam	N/A	No prior study or preparation
	Validation	A group of experts: Content validity (vignette, questions, and the expert's panel)	• 2 experts (T.P. and O.S.) • Evaluate the feasibility of the SCTs.	The evaluator sets up the desired number of questions and selects the strategy for new information.	• 2-3 independent reviewers verify the clarity and relevance of test items. • Pilot on one group of respondents.
Expert panel	Number of experts	10	32	N/A	At least 15
	Type of experts	Subject matter experts	Hospital-based internal medicine physicians	N/A	Hospital-based internal medicine physicians
	Recruit experts	• $\geq$ 6 years in practice • Familiarity with the students and the curriculum.	Involved in student education tasks within their hospital department.	N/A	• Formal certification in a field. • Specified number of years of practical experience. • Established a reputation for sound clinical acumen.
	Expected participation of experts	Ensure score reliability and develop the key score.	Developed the key score and 5 experts wrote qualitative comments.	N/A	Set the test's scoring grid.
Student's perspective					
Tool	Type of scripts	Ophthalmology	Internal medicine	Medical Education	Thoracic surgery, geriatrics, veterinary medicine, nursing, ethics, diagnosis, investigation, and treatment
	Students' level	Fifth-year medical students	Fifth under-graduate year	Pre-clinical	Students / Residents or Interns /Licensed health professionals
	Students' number	15 (3 groups of 5 students)	551 (various French medical schools)	N/A	N/A
	Technical support	paper	online platform (1h exam)	AppSheet-based SCT mobile app Google's cloud infrastructure.	Paper or online
	Pedagogic objective	Comparison of individual SCT and team SCT.	Comparison SCTs and classical MCQs4 and check SCTs reliability for under-graduate	Raising the usability of SCT by ontologies.	The basic tenets, theoretical concepts, and construction principles governing script concordance testing.

4. RESULTS AND DISCUSSION

Through a series of workshops, the collaborative team collectively generated and validated scenarios covering various themes. These themes include multidisciplinary perspectives, multicriteria analysis, multidimensional reasoning, and ontology. This discussion delves deeper into the methodology employed and offers examples of the scenarios we developed. To explore the potential of our combined SC and codesign approach, we conducted a series of workshops within a sustainable production course. A series of workshops were conducted to facilitate the codesign and validation of scenarios. The intention was to integrate various thematic areas such as multidisciplinary perspectives, multi-criteria analysis, multidimensional reasoning, and ontology. In the field of sustainable development, we brought together a collaborative team of bachelor's and master's students, as well as lecturers, professors, and pedagogical experts. Participant groups were modified at each workshop to ensure a better multidisciplinary perspective.

4.1. Vignettes and workshops

The vignettes present the context with a variety of industrial engineering situations and a brief challenge. Therefore, in the context of script concordance, candidates are presented with succinct clinical scenarios to analyze before responding to a set of questions aimed at soliciting opinions on potential diagnoses or management options as new information is introduced. Then a question is posed, which an engineer can experience in a real-life situation. Alternatives will be presented in a box at the bottom of the script and alongside the alternatives. In this way, new information will be presented to push the students' reasoning by intentionally incorporating information characterized by uncertainty and ambiguity. These forces thinking towards fewer possible choices, which is an opportunity to generate a solution that comes back to the initial requirements while forcing creativity. After this, a final box will present whether the initial choice of an alternative will be totally confirmed, confirmed, unchanged, invalidated, or totally invalidated. The three examples of vignettes have been designed for first-year industrial engineering students as part of a course on sustainable production. The theme of these vignettes is based on material efficiency, the possibility of integrating sustainability measures and standards, life cycle assessment, and logistic optimization.

In vignette 1, students are asked to understand the context of a car manufacturer that has to make strategic and long-term decisions to enter a green market. The following case presents the two solutions generally adopted to enter the green market and which can enable the company to stand out thanks to a strategic green advantage: producing an environmental product declaration (EPD) or implementing international ISO 14001 standards. Positive and negative points of view are then provided to encourage students to reflect further, then share their justifications and evaluate their choice in the latter case. In each case, we emphasize the collaborative nature and group discussion, focusing on organizing presentations where student showcase solutions to their peers. This aligns with a socio-constructivist learning approach.

Vignette 1

Context :		
A car manufacturer (ABC Inc.) must enter green markets and expand its global market within the next strategic plan horizon.		
If you think ...	**And we inform you that ...**	**Is your choice :**
A) Preparation and publication of the Environmental Product Declaration (EPD). B) Implementation of the ISO 14001 standard.	• ABC Inc. has encountered several difficulties in implementing ISO14001 due to a lack of commitment from the company management. • Other competitors in the market have not published EPDs, and the transparency of product life cycle assessment (LCA) results can be detrimental to the ABC brand.	1. Fully confirmed 2. Strongly confirmed 3. Unchanged 4. Strongly disconfirmed 5. Totally invalidated

Figure 1. Vignette 1

In vignette 2, the context provided for the student concerns their knowledge taught about the life cycle assessment (LCA) and the impact of logistics and transportation operations impact on sustainability. This vignette aims for the student to think about the logistics network implication with sustainability when the network is optimized and the implication of capacity management. After that, some insights regarding the potential outcomes of these solutions, which originate from the industry and are already implemented and tested, were shared. Subsequently, students can reflect on the appropriateness of their initial choices in light of this information in the last case.

Vignette 2

Context :		
In the life cycle assessment (LCA) or the product Z, ABC Inc. observes that logistics and transport have considerable environmental impact.		
If you think ...	**And we inform you that ...**	**Is your choice :**
A) Using an optimisation model to improve the existing logistics network. B) Increasing the degree of utilisation, particularly of trucks, and achieving full truck loads.	• ABC can define specific pre-determined days on which trucks serve designated areas. • Optimising vehicles can save 7 % in CO_2 emissions by using shorter distances travelled. • The company uses its own logistics department, and the recent survey shows a lot of stress and fatigue among truck drivers.	1. Fully confirmed 2. Strongly confirmed 3. Unchanged 4. Strongly disconfirmed 5. Totally invalidated

Figure 2. Vignette 2

In vignette 3 students were given the context of a surgical mask manufacturer and they had to apply sustainable action for an organization (XYZ Inc.). They are asked to choose between an action for the different life cycles of the product (design or end-of-life). The first solution is an eco-design practice, which is to change the

actual material for a more sustainable one. The second solution is the end-of-life approach, which is to invest in a recycling process. After that, positive and negative information is given for each solution and the student has to think if their initial solution chosen was the optimal one.

Vignette 3

Context :		
XYZ Inc. is a manufacturer of surgical masks and face masks and is keen to apply sustainable development practices.		
If you think ...	And we inform you that ...	Is your choice :
A) Changing the material of masks for more sustainable (eco-design process). B) Investing in mask recycling (End-of-Life process).	• The predominantly polypropylene blend of the face mask is densified into a crumb-like raw material that is used in plastic wood and composite decking applications. • Safety measures must be followed for the collection and recycling of waste personal protective equipment. • The company has no experience in reverse logistics. • The company has already invested heavily in suppliers and changing suppliers because replacing raw materials is a costly choice	1. Fully confirmed 2. Strongly confirmed 3. Unchanged 4. Strongly disconfirmed 5. Totally invalidated

Figure 3. Vignette 3

4.2. Preliminary Results and Observation from Sustainable Production Workshops

While formal evaluations are forthcoming, these preliminary workshops provided valuable insights into the effectiveness of our methods in achieving the objectives in Figure 4.

These initial observations, while requiring further formal validation, suggest the workshops promoted the development of the targeted objectives. This supports the potential of our approach to foster sustainability-focused critical thinking and decision-making skills, warranting further investigation and large-scale assessment.

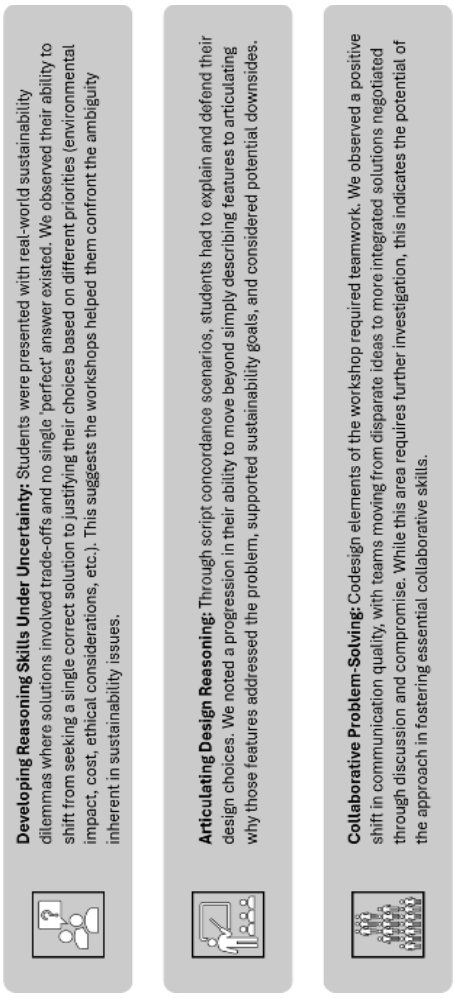

Figure 4 Preliminary Workshops Objectives

5. CONCLUSION

In conclusion, the integration of codesign and script concordance methodologies presents a promising avenue for enhancing engineering education critical thinking. The purpose of this research concerning Scholarship of Teaching and Learning (SoTL) is the exploration of a new pedagogical method in engineering, applied in medical education. Thus, contributing to the improvement of the understanding of teaching and learning processes, and providing valuable perspectives on how these methods can be applied to effectively train the engineers of tomorrow. By leveraging script concordance's capacity to assess reasoning skills under uncertainty and codesign's participatory approach to involve stakeholders in the design process, educators can cultivate a learning environment that prepares students to tackle real-world challenges effectively.

Our collaborative team, comprising students of bachelor's and master's degrees, lecturers, professors, and pedagogical experts, embarked on a process to develop script concordance scenarios tailored to sustainable development context. Through workshops and validation sessions, we ensured the scenarios covered multidisciplinary perspectives, multi-criteria analysis multidimensional reasoning, and ontology in the real industrial environment. While challenges such as cognitive biases of experts and limited application outside medical domains persist, our methodology underscores the versatility and effectiveness of integrating these approaches in engineering education. The comparison with existing studies on script concordance testing illuminates the diverse pedagogic objectives and student populations catered to by these methodologies, emphasizing their adaptability and relevance across educational settings. Moving forward, clear guidelines and continued research are essential to harness the full potential of codesign and script concordance in fostering critical thinking and problem-solving skills in future engineers. While the realm

of industrial engineering is vast and may seem daunting to fully explore, our journey in the two courses (assembly processes and sustainable production) has provided a glimpse into the possibilities of sustainable innovation. Over the past two years, we've embarked on a quest to challenge students to envision technical solutions that not only meet the demands of today but also pave the way for a greener, more sustainable future. This ongoing effort demonstrates our commitment to promoting environmentally friendly practices in the field of industrial engineering and supporting the sustainable shift that includes environmental and social aspects.

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