eLmL 2022

The Fourteenth International Conference on Mobile, Hybrid, and On-line Learning

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eLmL 2022

Forward

The Fourteenth International Conference on Mobile, Hybrid, and On-line Learning (eLmL 2022), held in Porto, Portugal, June 26 - 30, 2022., focused on the latest trends in e-learning and also on the latest IT technology alternatives that are poised to become mainstream strategies in the near future and will influence the e-learning environment.

eLearning refers to on-line learning delivered over the World Wide Web via the public Internet or the private, corporate intranet. The goal of the eLmL 2022 conference was to provide an overview of technologies, approaches, and trends that are happening right now. The constraints of e-learning are diminishing and options are increasing as the Web becomes increasingly easy to use and the technology becomes better and less expensive.

eLmL 2022 provided a forum where researchers were able to present recent research results and new research problems and directions related to them. The topics covered aspects related to tools and platforms, on-line learning, mobile learning, and hybrid learning.

We take this opportunity to thank all the members of the eLmL 2022 Technical Program Committee as well as the numerous reviewers. The creation of such a broad and high-quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and efforts to contribute to the eLmL 2022. We truly believe that, thanks to all these efforts, the final conference program consists of top quality contributions.

This event could also not have been a reality without the support of many individuals, organizations, and sponsors. We are grateful to the members of the eLmL 2022 organizing committee for their help in handling the logistics and for their work to make this professional meeting a success.

We hope that eLmL 2022 was a successful international forum for the exchange of ideas and results between academia and industry and for the promotion of progress in eLearning research. We also hope that Porto provided a pleasant environment during the conference and everyone saved some time for exploring this beautiful city

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Remote Working - The Webseries: Training Meets People Caring and the Liberating Power of Laughter

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***Abstract*— Adult motivation is the main issue about engagement, and in the recent pandemic it has been specially under surveillance in companies that have had to reorganize into remote working. People caring has rapidly become a strategic issue for Human Resources management, which used tools and training language to support organizational transformation, to engage people, to spread and promote the corporate culture even in remote working contexts, to recognize individual contribution and to support a sense of belonging. Training, therefore, even in phases of organizational change and transition, is a lever not only for learning, but also for managing people. The training experience presented in this paper regards best practices about WFH (Working From Home) in Sorgenia s.p.a. (Italian energy company) and highlights this double level of training objectives on learning and people caring. The adoption of a training approach oriented to known situations, practical contents and possible solutions, humorous video realization, characterized the illustrated didactic experience. Participants' engagement passes through the levers of familiarity of the situations (and recognition of possible or already known problems), accessibility of the solutions provided in a light and ironic way enabling individual resources. Engagement is promoted by a serial format (the web-series), which is periodically released and thought a humorous language. It is also interesting that engagement was pursued through active participation in the video production process to maximize the familiarity of the situations also through the recognizability of places and colleagues.**

Keywords-Engagement; humorous video-learning; web-series; people caring.

I. Introduction

Andragogical studies always tried to identify what influences adults' motivation to learn and what encourages greater engagement in training courses. There are two initial strands, one dating back to Thorndike [96] and inaugurated by the book "Adult Learning", in which it was experimentally demonstrated that adults are capable of learning but do it differently from children; and the other from 1926, with "The Meaning of Adult Learning" by Lindeman [58], that dealt in greater depth with how adults learn. In addition, many contributions are from psychotherapy (Freud and the subsequent), psychiatry, clinical psychologists and humanists, such as Maslow [61], who emphasized the role of a sense of security in human growth, and Rogers [88] who talked about learner-centered teaching in the same way that therapy focuses on the patient.

Training design is based on adult learning principles both to create an entire course or a single training session (synchronous or asynchronous), to be engaging, effective and memorable for those who participate. It is well established that adults first and foremost need to know why they need to learn something new, the benefits they might gain from learning and the negative consequences of not learning. Adults also need their self-concept to be respected, to feel autonomous regarding the content to be learned. Adults, after all, "are the experiences they had": they feel ignored or undervalued if their past experiences are not considered. Good training must therefore start from real experiences, accompany analysis and understanding, and use them as a starting point for improving future experiences. Adults are motivated to engage in training if what they are taught actually improves their ability to deal with tasks and situations in every day and working life. They ask and want the answer to the question: will what they learn really be useful to them? In line with the andragogical model, the role of the learner is therefore central: adults must become active participants in the process, supporting the trainer in the implementation of the whole activity, clearly in various forms, as summarized and rationalized in the 1980s by Knowles [54]. Bruner [8] distinguished between expositional and hypothetical modes of teaching: in the former, the teacher decides and exposes the contents and the student listens, while in the latter, teacher and student cooperate and the participant is not just a mere listener but a protagonist in the formulation of the contents. These concepts are all consistent with Knowles' andragogical model [54]. Andragogic theories and models on the value of engagement in learning have their roots unquestionably in pedagogical studies. Consistent with the andragogic approach, in Kolb's theory of Experiential Learning [56] we find not only the reference to the studies of Dewey, Piaget and Lewin but also the central role of concrete experience and reflective observation in the learning process. Experiential learning is a process in which knowledge occurs through observation and transformation of experience, i.e., not through the passive acquisition of notions, concepts and relationships. Kolb [56] picks up on Dewey's [34] "experience-reflection-learning" scheme, which highlights how the meeting point between personal development and education is fundamental. According to Piaget too, knowledge does not come from

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perception but from action and interaction with the environment: a process of adaptation that oscillates between assimilation and accommodation. Piaget [78] also talked about learning as a process: the knowledge path is fundamental, not just the achieved result. All learning is re-learning and constantly linking new learning to previous experiences. Experience and experimentation are two key words of training for Kolb [56]. It is also correct to highlight the "experiential approach in groups" in this analysis. According to Lewin [57] there is a relationship between group dynamics and the experiential approach. The group is unity, totality, dynamic reality: single person action modifies the group and vice versa. Despite its dynamism, the group will always tend towards balance between forces that tend towards disintegration. The group facilitates the integration of theory and practice: new learning emerges from reflection between the group's experience and theory. From the reflection on group dynamics, comes the interest in the value that the sense of belonging has in the engagement on learning paths. This view origin stems, on the one hand, from the deepening of positive parenting and, on the other, from modern approaches to learning design and gentle leadership. Although the concept of discipline is conceived with a view to raising responsible, independent and collaborative children, in families and schools, with respect and kindness, we have found in the concept of a sense of belonging touched on several times by the theoretical approach, a further confirmation of how fundamental it is, even in adults, to engage in participation, learning, sharing, availability, openness. "The primary goal of a child is: I just want to belong". "The child who needs love is very often the one who behaves in the least loving way". "An encouraged child does not need to behave badly". "Children behave better when they feel better". Trying to substitute the word child, in these sentences from J. Nelsen's text [74], it becomes evident that leveraging the sense of belonging increases engagement in training courses, in line with the main techniques for attracting attention and flipped classroom considerations. In his book "Happiness: a hypothesis", Haidt [47] talks about the human brain as an elephant and its driver. The driver is conscious, controlled thinking. The elephant is everything else and the opposite. It is gut feelings, reactions, emotions, visceral intuitions that make up a large part of the automatic system. The driver part of the brain is the rational part, then. The elephant wants, but the driver tends to curb the desire. However, if the elephant is not involved, the adult is not attracted, motivated, engaged. And elephants like stories, they like to feel like heroes of the journey, they favor the urgent, they are attracted by emotional resonance, by unexpected rewards, surprises, interesting questions, by collaboration and social proof, not always but sometimes by competition, if used sparingly. By play, by beauty, by fun.

The project presented in this work rise in response to the specific need expressed by the company Sorgenia Spa, to train its staff on the good practices to be followed to live the remote working in an effective, efficient and stress-free way by the development of the training proposal "Remote working- The Webseries" (during the Covid-19 pandemic). In the development of the training proposal "Remote working - The Webseries", it was important to experiment how the different dimensions touched upon in the andragogical approaches, combined with the enhancement of the sense of belonging, are fundamental to raising the level of engagement in training initiatives. This article recounts an experience and is structured as follows: in section I the theoretical context, in section II the need and the methodological response with related drivers, in section III the subject matter of the training, in section IV the work phases and the professionals involved, in section V the elements of transferability of the project, finally in section VI the insights gathered for future experiences.

II. TRAINING PROPOSAL "SMARTWORKING": TRAINING WITH THE WEB SERIES MEETS PEOPLE CARING AND INCREASES ENGAGEMENT

The training proposal "Remote working- The Webseries" addressed to all the staff of Sorgenia Spa (Italian energy company) during the Covid 19 pandemic and was motivated from the express desire and concern of the company to support its employees in the new working methods introduced by remote working.

A. Format

The Sorgenia staff were not only the recipients of the training intervention, but they actively participated as actors. This choice helped to strengthen engagement and identification, leveraging the need to belong, even stronger in a period of forced "distancing". Remote working- The Webseries is built on the stories of a small number of characters, in a familiar and ordinary environment, a block of flats revolutionized by the new rules generated by remote working. The protagonists are four condominium families, chosen with great attention to the values of diversity and inclusion. The web series, made up of nine episodes, winks at some typical situations of working life in remote working, touching on critical aspects but also on their inner value. It thus stages absurd, comical and yet decidedly realistic situations. And there is no lack of small "homages" to the TV series of the moment.

First episode is available at
https://vimeo.com/534372808/05c5b0b645

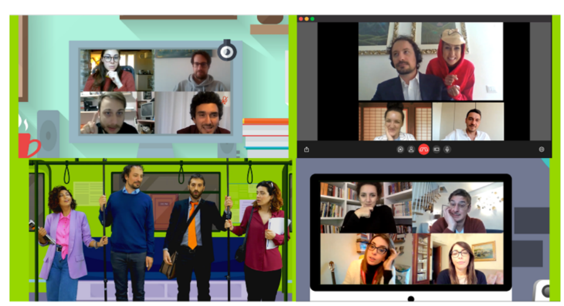

Figure 1. Example of a of one episode.

A short downloadable infographic (Figure 1) at the end of each episode proposes a recap of good practices, as a memo to keep handy to live your "connected" life with balance. It contains a few instructions to work better and smart safeguarding people's wellbeing, work-life balance, but also productivity, and narrated in a "typically Sorgenia" language that every employee could relate to. With the pandemic and the spread of remote working, the way companies communicate with their employees and the way they communicate with each other has also been transformed. The values of sharing and communication are a fundamental component of this new productivity paradigms, because they keep people together and allow them to overcome critical issues simply through dialogue. Sorgenia, a highly innovative company that is attentive to people's wellbeing, is a forerunner in this sense, because it believes and feels strongly that people's wellbeing is a value that affects motivation and productivity, helping to improve every aspect of the business. For Sorgenia, in line with the values it has in common with Piazza Copernico, taking care of its employees and their wellbeing passes through a clear trajectory, which the webseries wanted to follow to become a symbol of a culture, a way of thinking, a way of being and understanding the company. In addition to the classic incentives for workers, such as benefits of any kind and economic rewards that have a limited and temporary influence on motivation, there is a whole series of activities that can be introduced by companies to take care of their employees and their well-being, to make them feel a fundamental part of the company:

- offer trust, flexibility, autonomy; involve people: the more the employee is involved in company dynamics, the more productive he/she is.
- spreading the company culture by training management first, so that they lead by example.
- involve people in work strategies and objectives.
- build loyalty by acting on the sense of belonging, to make people feel part of the company and its development.
- improving communications, spreading and acting on the culture of sharing.

B. *Chosen method drivers*

Three drivers guided our methodological approach (Figure 2):

Figure 2. Method drivers

VIDEO EXPERIENCE: watching videos, as well as creating videos, is now part of everyone's experience. The society that has become increasingly audiovisual (Feierabend and Rathgeb, 2009) [36] and increasingly mobile (James, 2016) [52]. Smartphone itself is also increasingly a tool aimed at learning (Giannakos, Jaccheri and Krogstie, 2014) [44]. Video as an educational tool has great potential: it involves simultaneously several senses, is direct, immediate, achieves direct and emotional communication. Educational sciences talk about Kirkpatrick's so-called 'picture superiority effect' [53], referring to the greater likelihood that pictures have of being remembered than words. Neuroscience support the effectiveness of visual experience: about half of the resources committed by the brain at any given time are devoted to sight, according to Medina [63].

The effectiveness of video-based interventions in training is certain: video integrates and supports, through the visual dimension, practical and direct observation, the teaching-learning of good practices otherwise explained only verbally (Santagata, Zannoni & Stigler [92]). Video is valuable in modelling practices (Santagata & Guarino, [93]) and contributes to the development of a specific professional language (Minaříková, Janík, Píšová & Kostková, [67]); video promotes general and personal reflection - in the case of self-analysis on didactics, if we think for example of the practice of micro-teaching (van Es & Sherin, [107]); and is able to focus students' attention (Franke et al, [39]; Santagata, Zannoni & Stigler, [92]; van Es & Sherin, [108]). Video supports learning (Chambel, Zahn, and Finke, [19]): the reconstruction of real experiences, of the high degree of authenticity and realism, of the visualization of dynamic processes, which cannot be observed live (difficult to reproduce, dangerous, expensive) or which are difficult to describe verbally.

STORYTELLING: This does not only refer to images, but to the telling of stories, i.e., stories in which the viewer-learner can recognize himself. Because storytelling connects, promotes, facilitates remembering.

"Stories reshape information, transforming it into meaning", Duarte, [33]. Stories are powerful and indispensable tools of human beings to connect with other human beings. As neuromarketing teaches, the primitive brain reacts very positively to emotional storytelling. Everyone learns and builds his or her own meaning system from an early age with stories. Life itself constitutes a narrative as a story, according to Bruner, [8]. Narrative is innate to mankind, there is no evidence of civilization that has not used narrative: with the emergence of sociality and inter-human relations, narrative was born, an attitude that has always been present together with rationality. Each person is not only the sum of his/her experiences or the relationships he/she establishes, but even more so the sum of his/ her stories and the contextual frames that are created around the stories (Bruner [8]). Narrative thinking is, moreover, a specific cognitive mode through which individuals structure experience and construct interaction with the external environment. Understanding actions, behaviors and experiences according to the typical mode of narrative thinking is a fundamental operation that guides the human mind in the attribution of meaning and significance (De Rossi, [29]). Restak [84], a neurologist who has studied the role of neural networks in learning processes, maintains that narration modifies the structure of the brain as much as personal experience. This claim is also supported by the behaviour of so-called mirror neurons, which are dedicated

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to recognizing the emotions of others. Stories can be experienced emotionally and have meaning for each of us because these emotions trigger a process of identification with the characters who live those emotional experiences. Researchers including Hung [51] have now clearly demonstrated that storytelling used for learning has positive effects on motivation, knowledge consolidation and awareness building.

HUMOR: and then you want to laugh and make people laugh. Laughing relaxes mind and opens it up to new stimuli, it helps to fix situations in memory and promotes learning, because mind does not distinguish between spontaneous and induced laughter. In general, laughing always produces great psychological and physiological benefits. According to Hippocrates and Galen laughter inevitably influenced the course of an illness. Gelotology (from the Greek ghelos= laughter and logos= science; the science of laughter) studies and applies laughter and positive emotions for the purposes of prevention, therapy, rehabilitation and training. This science has ascertained that in our bodies there are numerous connections between the nervous, endocrine and immune systems. Any alteration to one system also affects the others, influencing the overall health of an individual. Laughter activates the glands that produce endorphins, which stimulate and strengthen the immune system. Various studies over time have richly demonstrated the power of laughter in different areas of life. Patch Adams, the father of clown therapy, together with other doctors, has made great contributions to the study of the effects of positive emotions. And today, laughter therapy also enters homes and offices. Many coaches use laughter to facilitate the achievement of serenity, well-being and success in private life and at work. Warm cognition or warm learning undoubtedly makes it possible to learn better and faster, by using smile and fun. Irony produces solidarity, cohesion, inclusive dialogue, but also adaptability, resilience and questioning. Laughter is a fundamental aspect of antifragility. It is no coincidence that we are increasingly talking today about humor training or even humor coaching. Smile:

- resizes limiting beliefs and reactivates positive attitudes towards potential and limits.
- activates psychological and neural resources that awaken the body and mind from moments of immobility.
- deconstructs habitual patterns of perception.

This allows to see, feel and therefore experience things from another point of view. It stimulates lateral thinking and creativity, facilitates the magical synthesis of fantasy and reality. Davies [23] hypothesized that the origin of the forms of humor linked to tragedies or catastrophic events is also a consequence of the widespread and massive media coverage of such events, as was also the case during the Coronavirus pandemic. It seems that the continuous media narrative plays a significant role in how the pandemic emergency is perceived, generating increases in stress and anxiety (Garfin, Silver, & Holman, [43]). In this scenario, as in the past, humor has been and is a possible way of salvation (Fessell, [37]), "[...] the most powerful defense mechanism" (Freud, [41]), with different functions acting on physical and mental well-being, quality of life and perception of events. The use of humor or comedy helps to overcome stressful moments (Fritz, Russek, & Dillon, [40]) or to mitigate their negative effects (Pietrantoni & Dionigi, [79]). More generally, experiencing comic situations supports mental and emotional well-being (Borcherdt, 2002[5]), has a beneficial effect on health conditions and mood (Marziali, McDonald, & Donahue, [62]; Vagnoli & Dionigi, [106]) and allows for a more positive evaluation of experiences and quality of life (Rivista italiana studi sull'umorismo, [86]).

III. CONTENT AND LEARNING PATH

The content of the webseries was divided into 9 episodes:

- Video call: your survival kit (episode zero)
- Remote working- how to live it well
- The effects of remote working
- Video calls: how to deal with them
- A good video presence
- Dive into deep working
- Video calls: instructions for use
- Managing a team remotely
- Healthy misunderstandings

The development team was made up of different professionals: learning experience designer (trainer), scriptwriter (trainer), actors, video maker, web designer, graphic designer, developer, social media manager, as well as Sorgenia representatives and staff.

An article in “Sorgenia Up”, the company's official magazine, kicked off not only the training campaign, but also the related social experience, to increase the interest of the company's population in the release of the episodes, which ended with the publication of the classic bloopers. In a difficult moment of health emergency and from the company's need to communicate to its employees, who had been remote working for months, “We are here”, and the idea of the dedicated web series was born.

The proposal was a targeted training and information initiative, but also a people-caring operation aimed at providing employees with 'good practices' to deal with remote working positively, effectively and without stress. The "distance" in carrying out work activities did not affect the sense of belonging to the company, which continued unabated to take care of its employees.

IV. WORKING METHOD

Compared to a classical model of designing and developing content for digital learning, in this project some phases were specifically taken care to make content and method functional for the objective to promote participants high engagement. In the following, indications on the most peculiar phases of the project are given.

1) Client material receipt and demand analysis

The project started with a careful analysis of the client's needs. In several meetings, the client's values, intentions, objectives and received reference materials were brought to light. At the end of the analysis, a project document was produced which presented the methodology and action plan.

2) Drafting of the macro-design (number of episodes, subjects, campaign calendar)

The design work started with the analysis of the materials/interviews with the owners, to structure a preliminary map of the learning experience. The next step was to identify the learning objectives, as "the description of a performance that students must be able to show in order to be considered competent" by Mager [60]. Specifically, the learning objectives' tree is hierarchical structure, constructed in relation to content, explicit in the results to be produced and enriched with indications of complexity according to Bloom's taxonomy [4]. Design and development of two prototypes, differing in narrative style and graphic format and client's choice of prototype

3) Script editing

For the design of videos Piazza Copernico uses a storyboard model inspired by real screenplays, with essential editing, typical of the genre. This format is used indiscriminately for videos with live actors, such as video lessons, sketches, commercials, and for graphic videos such as motion graphics, whiteboard animation, etc. The script is divided into several columns containing: narration and dialogue, scene description, settings, character mimicry, graphic effects and text on screen, music, filming materials, location, etc.

4) Script validation

5) Casting actors and extras

Piazza Copernico has professional actors, with experience in theatre and cinema/TV, who are able to perform and enhance the scripts at various levels. In addition to the actors, in order to act on engagement, enhancing the sense of belonging to the project and the company, Sorgenia workers also participated in the role of protagonists, who were available for filming and interpreting the scripts.

6) Filming

For videos played by actors, Piazza Copernico shoots in its own studio, or in other indoor or outdoor locations, depending on the needs of the script. In this case, both studio filming, on green screens, and in real locations were carried out, as well as direct screen casting to reproduce remote working situations and video calls. The operator/director and scriptwriter cooperated constantly throughout the production. Sorgenia's HR representatives launched a company contest for employees to participate as actors: the countless entries to the experience confirmed the interest in the initiative. A short casting among people was carried out and 10 employees were selected to participate in the filming.

7) Design and creation of final infographics

Figure 3. Figure: Infographic example

8) Editing and post-production

Made by professional video makers with dedicated software such as Premiere and After Effect, suitable for editing and compositing, with the possibility of adding text, motion graphics and VFX elements of various kinds, designed and planned by the developer in consultation with the director and screenwriter.

9) Tracking preparation

10) Debug and publishing in Piazza Copernico's LMS (Learning Management System)

The episodes were assembled in a scorm package, with content structuring that follows a linear and sequential logic: it is necessary to complete the fruition of each episode, before being able to move on to the next one. The engine used, standard scorm, is accessible and mobile friendly.

11) Serial delivery

The training campaign lasted approximately six months (May - October 2021). A calendar for the publication of the episodes was structured and shared with the company. The episodes were published every 2-3 weeks, also in consideration of Sorgenia's working calendar (e.g., holidays).

V. Results

In the pilot phase, the results were collected from the point of view of the perceived impact by the management, since by design choice no direct ex post evaluation tools were included on the training experience. Instead, it is important to consider the impact on the working climate and processes, as assessed by the company, internally and independently from the webseries design group.

The evaluation carried out within the company is summarized in the contribution of Dr. Silvia Guidi (Diversity, Inclusion & People Care, Innovation & Development Department of Sorgenia SpA) commenting on the experience: *"Remote working - The web series was a new learning experience for us: thanks to our collaboration with the Piazza Copernico team, for the first time we used irony to transfer valuable content and we did it in the midst of a pandemic, when the context around us was anything but*

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'playful'. Hence the decision to convey instructions on how to best live our new 'connected life' in a light-hearted and fun way that was in line with our values, among which the principle of 'HAVE FUN' stands out, which translates as follows: in Sorgenia we face the challenges we face with enthusiasm and passion, collaborating with each other and encouraging self-fulfillment in everyone. In addition, we directly involved our colleagues through a 'contest' that allowed them to play a leading or co-leading role in some episodes of the web series, alongside the actors of Piazza Copernico: another aspect that generated engagement and helped make this training project even more interesting and stimulating for us at Sorgenia".

Future corporate objectives include adopting the developed model as applicable to all content of universal interest to the corporate population, where it is essential to share best practices and corporate values.

VI. Conclusions

The project was strongly oriented towards training engagement, as important factor for a broad and widespread participation for remote workers, and to actively promoting the best fundamental practices for working effectively and maintaining adequate wellbeing and a good quality of life.

In transformative organizational contexts where practices and values need to be conveyed clearly, quickly and effectively, traditional training paradigms are out of place. engagement is the winning factor to be achieved and promoted. In the project, engagement was pursued at all stages of the project, i.e.:

- in the design of real-realistic situations related to the working context,
- in filming by involving company people and places,
- in the direct, ironic and emblematic language,
- in dissemination on the company's social networks.

The fundamental lever used was the recognition/ identification that created closeness in single participant to the stories, and the sharing among the participants (who recognized the situations experienced from different points of view), as well as the ironic key to demystify the criticality in favor of a more solution-oriented reading.

The project has shown multiple potential transferability elements, as this methodology is exportable to other contexts, contents and organizational change process. In terms of content, the episodes are built on typical work routines of many companies, which could benefit from the dissemination of good practices to experience remote working effectively and positively. From the point of view of method, its effectiveness was demonstrated precisely in its ability to shorten the distance between personal experience and organizational experience, helping to reduce the emotional distance from the organization, and encouraging involvement. In terms of development, all material was used, even errors (bloopers), which helped to interest people in the content. From the training point of view, in fact, the aim of this type of training material is to use formats typical of other contexts (e.g., television), to interest people in the topics of interest, then providing content (e.g., infographics, materials, etc.) to refocus the training meaning of the video material. This refocusing on training is fundamental to avoid the risks connected to these types of formats, which, by focusing attention on situations, can risk a blurring of the underlying training meaning. Therefore, authors suggest some caution in method use and dissemination, alias the *reality ironical copy* (ironical replication of reality). It is necessary to strengthen the collection of emblematic stories and concrete examples at an early stage, to strengthen the link with the reality. It is also strategic involving company staff more actively in the material production. Finally, a key winning element is to include tools for collecting and listening to the real effects in the working context (e.g., surveys, communities, focus groups, kpi analysis.). Only through a perceptions and meanings analysis on actual difficulties, it will be possible to design and redesign videos and the learning mix to be most suitable to support the organization's objectives.

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Attention and Meditation Quantification Using Neural Networks

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***Abstract*— The advancements in dry-sensor technology have enabled easy brain activity data collection thorough a variety of portable brain computer interfaces based on electroencephalography (EEG) technology. This paper proposes a data analysis framework for evaluating the impact of various brainwave frequencies (delta, theta, alpha, beta, and gamma) on human attention. Multiple working scenarios have been created for the subjects targeting to enhance their level of attention. To properly evaluate the data by utilizing the artificial neural networks, several hypotheses have been defined. Their purpose is to group the brainwaves into low to medium frequency type and high-frequency type with the attention and meditation values and attempt to establish interconnections.**

Keywords-brain-computer interface; attention quantification.

I. INTRODUCTION

The study of the brain activity is a fascinating research topic, due to the inherent complexity of the human brain. The brain has remarkable and uncharted abilities to capture, integrate and process data. It can be seen as an enormous network of neurons that enables vast data processing potential. It also acts as a storage center and control, where information coming from senses merge and undergo several complex processes to help in the decision-making processes. Although the full extent of the brain's capacity it yet to be discovered, there are encouraging research avenues that advocate for life quality increase, recovery and rehabilitation for a plethora of medical conditions, such as stroke [1], paraplegia [2], Parkinson's disease [3], Alzheimer disease [4], etcetera. With the advent of dry sensor Brain Computer Interface (BCI) technology, capturing the brain's electrical activity can be done on a large scale. A BCI acts like a platform that detects and records small fluctuation in electricity generated by the cerebral cortex. The electrical activity of the brain is monitored in real-time using an array of electrodes, which are placed on the head skin in a process known as electroencephalography (EEG). The EEG readings represent the user's perception, and reaction to various stimuli from the surrounding environment. The brainwave frequencies depend upon the firing speed of the neurons and the number of neurons that fire simultaneously.

BCIs connect the brain with the computer by enabling the brain-waves raw data transmission, called neurofeedback. BCIs present new methods to enhance human-computer interaction, and opens new avenues for augmenting human abilities. One promising research direction evaluates brain functions via BCI and cures people with brain or spinal injuries via micro-grains implanted into the brain [5]. Analyzing the brainwave data, input-output patterns can be established with the aid of machine learning. The subject's intentions are correlated with specific outside actions.

Attention and meditation are internal underlying activities that occur continuously and are manifested either in a conscious or unconscious manner. Meditation does not have a rigid definition or live representation; however, the desired purpose through meditation is to reach the so-called "Zen" state of mind, to reduce pain or anxiety. Meditation aims to better the mindset and to train the mind in order to react properly in demanding situations. Attention is an internal process represented by an absolute mind state of full focus on a given action. Attention is the capability of concentrating exclusively on a specific task, while being able to ignore other external or internal triggers. The borderline between attention and meditation is shallow. One can be attentive while in meditation and vice versa.

In this article, a new method is proposed to evaluate and objectively quantify the attention and meditation levels of the subject with the aid of the NeuroSky BCI as a hardware device and the Neural Network software. The results are evidencing some patterns between the type of activity the subject is involved in and the brainwaves at that particular time. Based on the EEG data collection during various scenarios, the aim is to decipher a nuanced understanding of the brain during attentive and meditative stages.

Attention Levels:

- Arousal: Refers to our activation level and level of alertness, whether we are tired or energized.
- Focused Attention: Refers to our ability to focus attention on a stimulus.
- Sustained Attention: The ability to attend to a stimulus or activity over a long period.

Brain signals can be classified into five basic categories, Delta Waves (.5 - 3 Hz), Theta Waves (3 - 8 Hz), Alpha Waves (8 - 12 Hz), Beta Waves (12 - 38 Hz), Gamma Waves (38 - 42 Hz).

Rest of the paper is organized as follows. Section 2 presents an overview of the evolution of BCI and their applicability. Section 3 depicts the software and hardware components utilized, alongside the deployed methodology. Section 4 provides the hypotheses and scenarios of the experiments. Section 5 outlines the captured results for all hypotheses and scenarios.

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II. Related work

A BCI is a non-invasive approach of retrieving and monitoring cerebral activity (EEG recordings), and its methodology is seamless; as a result it has a wide range of applications. BCI's and their associated data are used in neuroscience, cognitive science [6], psychology [7], psychiatric branch [8]. BCI's area of application has extended over the years to neuro-management [9], neuro-marketing [10], human interactions, and engagement.

An impressive research effort has been conducted towards improving life in many aspects by utilizing brain-controlled techniques, including the alleviation of comorbid psychological disorders. The employment of specific neurofeedback protocols serves as a remedial treatment for Attention Deficit Hyperactivity Disorder (ADHD) [11] and Autism Spectrum Disorder (ASD) sufferers [12], normalizing irregular neural activity that occurs during high anxiety episodes. Therefore, in some cases neurofeedback is considered an alternative for the pharmaceutical treatment.

Other groundbreaking applications of neurofeedback include prosthetic and robotic arms, human gait [13], emotion detection, and classification [14]. Newer approaches suggest significant advantages in employing EEG interfaces in workplace optimization [15] through stress recognition [16], in neuro-marketing [17], decision factors, and hyper scanning [18] that follows the brain processing, sustaining synchronization of actions. With the fast growing horizon in life quality improvement, a plentitude of EEG based palliative remedies occurred. Among those, BCIs are employed both invasively via MEA (microelectrode array)/ via brain micro implants and non-invasively via electrodes placed on the head, i.e., dry/wet biosensor technology. The biosensors detect minuscule amounts of electricity generated by the brain and drive various protocols quantifying the meditation and attention levels (e.g., for the Attention Deficit Hyperactivity Disorder and Autism Spectrum Disorder cases). Meditation has benefits in subsiding the severity of ADHD [19], ASD [12], depression, stress, anxiety, Obsessive Compulsive Disorder (OCD), personal disorders [20].

Although many studies focused on exploring the brainwave feedback via EEG in the sphere of neuroscience, its application realm broadened and so did the discipline fields as shown in Figure 1.

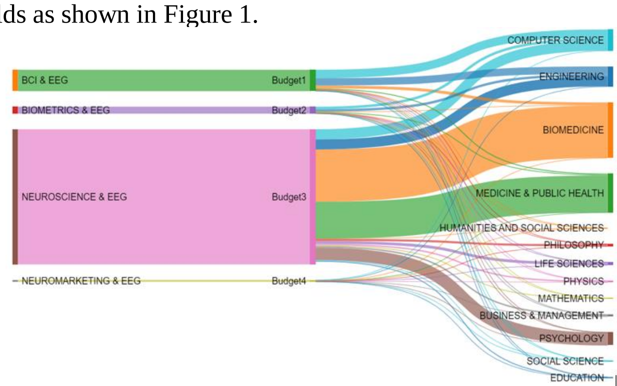

Figure 1. Systematic mapping of EEG applications based on disciplines.

The systematic mapping depicted in Figure 1 was carried out on the Springer database by using the search strings indicated on the left, the results were filtered on their release date between 2000-2022.

Over the last two decades, the interest in the BCI research topic has exponentially grown. The top five activity fields that are tightly connected to the BCI are computer science, engineering, biomedicine, medicine and public health and philosophy refer to Figure 2.

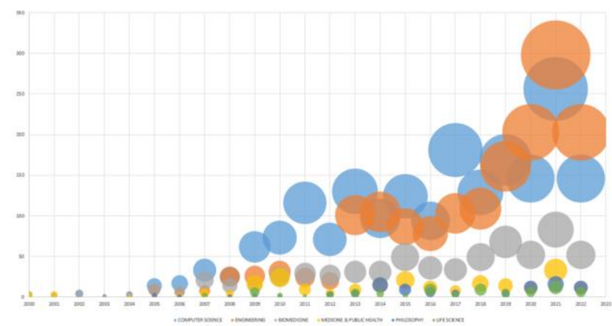

Figure 2. Time evolution of BCI interest based on the research topic.

The brain produces five types of waves (Delta, Theta, Alpha, Beta, and Gamma) continuously and for each BCI recording, only one of the brainwaves will be dominant having the greatest intensity. In case of a single BCI dry sensor, its placement is significant in the securing the best neurofeedback. For instance, the prefrontal region of the brain is in charge of problem solving, generating multiple prosaic/routine like judgments, planning, behavior and emotions. The Pre-Frontal Cortex (PFC) functions are complex cognitive functions as well as shortsighted behavior, to be able to act with a goal in mind, and self-control. It receives the sensory information, plans resources based upon that, and keeps close communication with other regions of the brain to enact a reaction. The reactions have a broad range, and most importantly, they include redirection of attention.

Five types of brain signals are scrutinized, each of them epitomizing special features, such as frequency, amplitude, shape, activation stimuli, as well as illustrating their own peculiarities related to the physiological facet. The EEG records the brain activity in employing the operating principles of a differential amplifier, which collects two electrical inputs and displays the output as the difference between inputs. Extremely beneficial while addressing very small electrical signals, such as the ones that appear in the brain.

Initially, the literature sustained the idea that the low-frequency brainwaves directly influence the meditation level, and the high-frequency brainwaves are associated with high attention levels. As the research interest in brainwave activity grew, studies have shown that high-frequency brainwaves are also developed while meditating.

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III. System Components

The systematic sequence of processes employed in the paper encompass both a hardware (NeuroSky Headset) and a software component (MindWave of NeuroSky and NeuronalNetwork Tool of MatLab). The initial phase is the raw brainwave signal acquisition, followed by an intrinsic pre-processing step to for feature/pattern extraction.

A. Hardware Component

The project employed the Neurosky BCI (link), to collect EEG data. As depicted in Figure 3, the NeuroSky's headset fundamental elements are the sensor (electrode) that records the EEG data, supported by the ear clip that acts as a ground and reference. The electrode and the ear clip of the Neurosky BCI record the brain activity by using the operating principles of a differential amplifier, which collects two electrical inputs and displays the output as the difference between them.

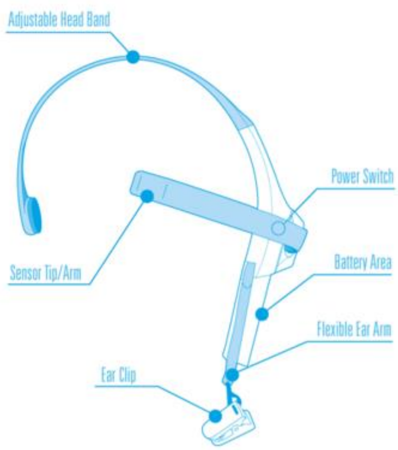

Figure 3. NeuroSky HeadSet.

The placement of the dry electrode on the Pre-Frontal Cortex (PFC) region of the frontal lobe is due to the fact that the frontal lobe serves the executive function, making decisions and delegating the output supported by the motor nerves to the entire body.

B. Pattern Extraction Neural Network Design

The process diagram shown in Figure 4 portrays the three significant steps followed in pursuance of attaining ready-to-use data for the neural network procedure.

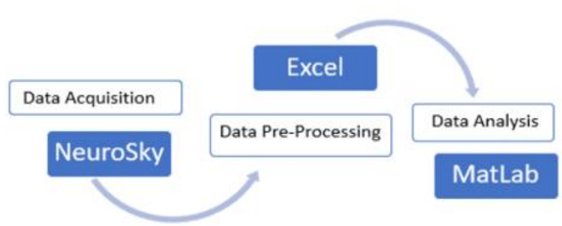

Figure 4. Process diagram.

For pattern extraction we employed the Neural Network application (NNstart) of the MatLab environment. This tool is designed to mimic the human neuronal system by artificially creating a neuronal network, modeled by multiple layers of neurons. There are three types of neural layers: input, hidden and output layer, as illustrated in Figure 5. Within the NNstart, neurons' pairing is illustrated by connection weights of neurons, each neuron has its own weight and bias, which is associated with storage of information and is fed into the transfer function that serves as a liaise model and translates the input variables to output variables.

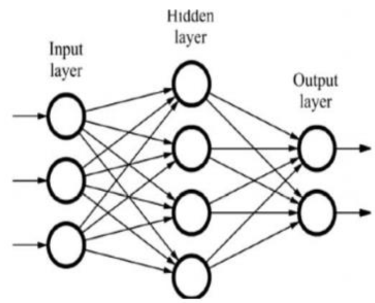

Figure 5. Multi layered neural network.

The pre-processed EEG recordings (input data) are randomly segregated as follows:

- Training - used for training purposes; these are presented to the network during the training and the network is amended in accordance with its error.
- Validation - used to validate that the network is generalizing and stop training before overfitting. The validation data are used to measure network generalization, and to cease training when generalization stops improving.
- Testing - used as a completely independent test of network generalization. These have no effect on the training itself, however they supply an independent measure of network performance during and after the training.

The input data causes the internal state of the neurons to change in accordance to the nature of the input and triggers neural activation. The target is the desired output for a given input. The output is as close as possible to the target by adapting the weights of each node in the network. The output of the node is the weighted sum of all inputs and is processed by using an activation function that determines the behavior of a node.

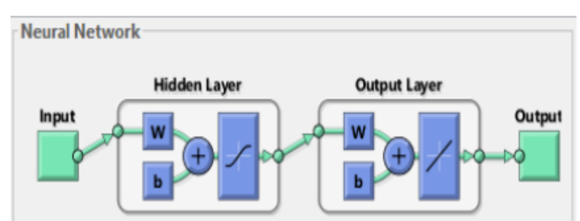

Figure 6. Artificial Neural Network Structure MatLab.

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Figure 6 epitomizes the structure of the neural network in MatLab; additionally it presents the input-output connection scheme.

The first part of the functional diagram is represented by the NeuroSky headset for raw brainwave data acquisition; Followed by the NeuroSky's embedded pre-filtering, improving the quality of the raw data gathered from neuronal activity (weak electrical signals), eye blinking (identified as a skin stretch response).

The pre-processed data is subjected to multiple algorithms to be analyzed (feature extraction included) and properly interfaced for the user. The result is a document containing data values for each brainwave defined by the headset's protocol (Delta, Theta, Alpha1, Alpha2, Beta1, Beta2, Gamma1, and Gamma2).

A proprietary algorithm within the Neurosky's software called NeuroExperimenter computes the levels of attention and meditation. For each recorded dataset, there is a time stamp, and the sample rate is 1Hz. The second step is to pre-process the data and prepare it for the actual analysis in MatLab software. The pre-processing is represented by engaging the data feature engineering technique, which aids the prediction percentage in machine learning algorithms, handling null values, adequate data import into the NNstart, and dataset split into subsets. The third phase achieves the pattern extraction with the aid of the NNstart of MatLab.

C. Parameters Configuration

To effectively analyze the NeuroSky recordings, input and target variables need to be correctly defined within MatLab NNstart for each experiment. The operating scheme of NNstart MatLab is the following:

- Initialize the weights
- Compute the error (difference between output and desired output)
- Re-compute the weights
- Adjust the updated weights
- Repeat the process for all training data until the error reaches an acceptable level

An epoch represents one training iteration of the data though the network, this procedure is repeated until a satisfying outcome is obtained. A result that is labeled as satisfying entails an error that is below the threshold value or the minimum error (difference between the desired output and the achieved output). The type of network (feed-forward), the number of neurons on the hidden layer, the training algorithm and inputs and targets vectors must be defined. After uploading the data vectors, the program divides it into three data categories: training, validation and testing, each associated with a percentage.

The methodology featured in Figure 7 represents a graphical illustration of the pathway pursued in order to reach the appointed results.

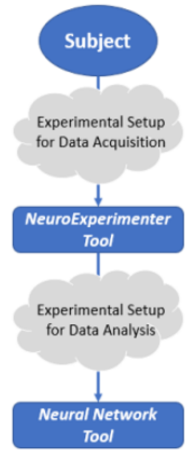

Figure 7. Working methodology.

IV. EXPERIMANTAL SETUP

The following hypotheses are considered:

- H0 Both meditation and attention levels are equally affected by all eight types of brainwaves defined by the NeuroSky headset protocol (Delta, Theta, Alpha1, Alpha2, Beta1, Beta2, Gamma1, Gamma2).
- H1 The meditation level is equally affected by the low to middle frequency brainwaves (Delta, Theta, Alpha1, and Alpha2).
- H2 The attention level is equally affected by the high frequency brainwaves (Beta1, Beta2, Gamma1, Gamma2).
- H3 contrasting the H2 hypothesis, the meditation level is equally affected by the low to middle frequency brainwaves (Beta1, Beta2, Gamma1, and Gamma2).
- H4 contrasting the H1 hypothesis, the attention level is equally affected by the high frequency brainwaves (Delta, Theta, Alpha1, and Alpha2).

By employing the hypotheses approach, there is a sense of inclusiveness, which might open new research avenues. In order to complete the cycle, two datasets have been gathered. Certain scenarios establish the data acquisition phase:

Dataset 1:

- Scenario 1 - Coding - spent 11 minutes working at coding a math game.
- Scenario 2 - Simple math - spent 2 minutes doing simple math.
- Scenario 3 - Reading - spent 2 minutes spent on reading the article When Biking and Bears Don't Mix (Random article on NY times).
- Scenario 4 - Social Media - spent 1 minute looking at social media on the phone.

Dataset 2:

- Scenario 1 - Baseline experiment for 5 minutes in a quiet room. The subject is required to remain silent, stare straight forward at a stationary wall, do not move.

- Scenario 2 - Simple math for 2 minutes obeying the baseline requirements, except the fact that the subject must look at the computer's screen and solve math exercises that consist of addition of two numbers, both being under 100. The math exercises must be taken in the subjects' head and the solutions must not be said out loud.
- Scenario 3 - Visual experiment for 2 minutes that respect all the criteria mentioned into the baseline scenario, except the fact that now the subject will be looking at different GIFs or animated pictures.
- Scenario 4 - Audio experiment contains three sub-scenarios that are wrapped into one; the subject will listen to three different audio files at different times, each audio listening performed by the subject must be followed by the brief two-minute baseline break. The audio files are very distinct from one another, the first and second files contain contrasting music genre and aim to determine a personal taste or a yes/no reaction. The third audio file is consisting of white noise and it is used to observe the subjects' reactions to it. The duration for the first audio experiment is five minutes, the second one lasts six minutes and the third one four minutes.

V. EXPERIMENTAL RESULTS

The main parameter that has been closely investigated in the experimental analysis is the regression of the artificial neural network for all of the hypotheses, scenarios and subjects. Regression illustrates the connection between the output variables and input variables. The regression values were acquired after training the neural network for each of the cases.

The first dataset represents the data from a single subject, that performed four scenarios, coding, reading, simple math and social media browsing. For this particular case, Figure 8 portrays some trends and patterns, that can be identified with the assumption that the data is influenced by the physical and emotional state of the subject and their disposition at the time of the recording. The overall score for all the scenarios is the highest for hypothesis 0, which states that all brainwaves impact the levels of both the attention and meditation. One can notice that the highest reading was registered by employing hypothesis 0, for the reading scenario and the lowest regression score for the reading experiment is when employing hypothesis 2.

Dataset 2 is comprised of the data gathered from two subjects that performed exactly the same activities. One pattern that arises is that in case of H0, all of the regression recordings associated to the scenarios have the highest values, indicating a better fit.

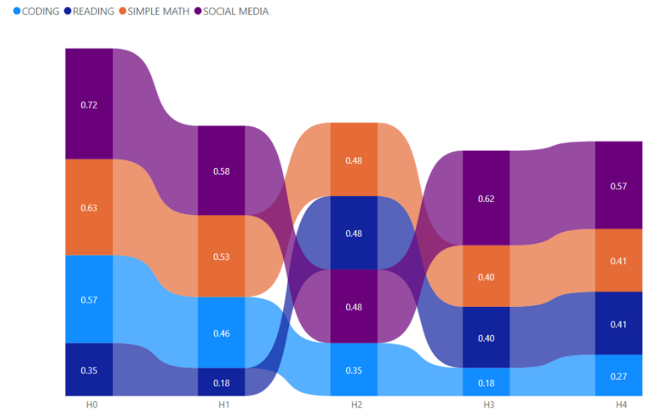

Figure 8. Dataset 1 Experimental Data Comparison Based on Hypotheses and Scenarios.

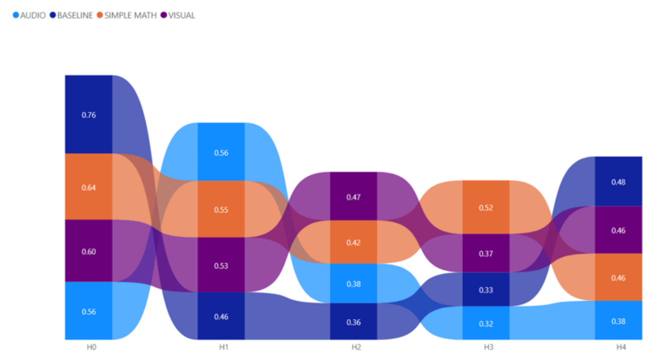

Figure 9. Dataset2 - Subject 1 Experimental Data Comparison Based on Hypotheses and Scenarios.

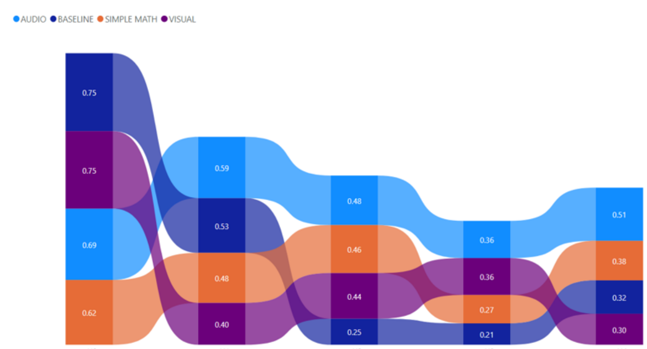

Figure 10. Dataset2 - Subject 2 Experimental Data Comparison Based on Hypotheses and Scenarios.

Based on the results featured in Figure 9 and Figure 10, an appealing parallel ensues. The Baseline activity developed a significant regression value for both participants when considering hypothesis 0 and a low regression value for the rest of the hypotheses. The Audio scenario employing H0 establishes that the second subject has an improved response to audio stimuli in regards to attention level, scoring a higher regression result in comparison to the first subject; The results for the rest of the hypotheses in the Audio scenario for both participants are similar. Hypothesis 0 in the Math scenario is still as effective as before, both subjects scoring a

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high regression value for it in contract to the other hypotheses. A dichotomy is present when H3 is inspected for the Math experiment, the second subject's regression value exhibits a mismatch, scoring a low regression level, juxtaposing with the first subject's regression score. The Visual result reiterates the hypothesis 0 as being advantageous in the case of these two participants. The methodology engaged throughout the paper is an enabler. By enlarging the pool of subjects, the diversity of the scenarios and by utilizing the presented method of monitoring attention and meditation levels can provide instructional designers with knowledge for better designing the learning mix, evaluating required cognitive efforts to foster attentional processes and ensure better training results.

VI. CONCLUSION

Objective attention quantification is a complex task. However, attention is an important ingredient of learning. BCI provide a noninvasive way to collect brain activity in real time and may be employed in user attention quantification. In this paper, we evaluate several learners as they perform different tasks and discuss various methods to analyze and compare brainwave data. We observe common patterns for all users, despite the limitations faced in data interpretation. The goal is to expand and increase the experiments user base to detect patterns in user attention based on the audio-visual content presented. We believe that BCI can be employed successfully in improving the learning outcomes and fine tuning learning materials for adult learning.

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Designing and Implementing a Lightboard Learning Experience for Instructors Through the Learning Engineering Process

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***Abstract*—The Residential Education team at the Massachusetts Institute of Technology (MIT) followed the learning engineering process to design and implement a learning experience for instructors that prepares them to create videos for students using the Lightboard lecture capture system. The content of the online module was designed to emphasize evidence-based instructional practices, primarily through video examples of instructors experienced in using Lightboard demonstrating these best practices. A critical component of the learning engineering process is iteration, and the team navigated two major iterations to the implementation of the learning experience. This paper details each iteration highlighting the specific design decisions and design justifications, and forwards the practice of tracking such work throughout the implementation. Design decision and justification tracking is a practice that can help a team ensure an implementation remains learner-centered and backed by evidence from the learning sciences, while taking into account other factors in the implementation context such as constraints of the technology, timeline, and institutional resources. The paper concludes by underscoring the practical implications of tracking design decisions and justifications for a team following the learning engineering process to implement effective instructor learning experiences.**

Keywords—learning engineering; learning experience design; design process; instructor training; higher education

I. INTRODUCTION

In the summer of 2020, the Residential Education team at the Massachusetts Institute of Technology followed the learning engineering process [5] [7] to design and implement a learning experience in the form of an online module for instructors that aimed to support their efforts in creating Lightboard videos. Lightboard videos are a form of lecture capture where instructors write on a lighted glass pane facing a camera [1]. Making explicit the underlying assumption of how this work supports the community of practitioners, it is assumed that impacting student learning begins with instructor preparedness to effectively utilize the Lightboard technology based on pedagogical actions grounded in the learning sciences [6]. Given this, the goal for this specific learning experience was to make instructors aware of best practices backed by evidence from the learning sciences and exemplified in authentic demonstrations of these practices enacted by colleagues from across the institution.

The design team engaged in several key learning engineering practices to achieve this goal, including cycles of creation, implementation, and investigation [4]. This paper will focus on the implementation part of this process, specifically key design decisions that were made as the implementation context changed over the course of a year and a half and resulted in two major iterations. The initial design challenge was to create a learning experience to address the need for instructors to be supported in Lightboard technology in the context of COVID-19 emergency remote instruction, where the pedagogical affordances of Lightboard videos could help address teaching and learning challenges of the time. This implementation context then changed as the institution adopted a new learning management system, Canvas. This led to a key pivot in the approach, and the second design challenge of adapting the learning experience to Canvas so that it increased awareness of and lowered instructors' barrier to entry to the learning experience.

Ensuring that the reworked learning experience remained learner-centered and effective for instructors was the central focus of the second iteration of design. To help navigate these evolving implementation conditions, the practice of tracking design decisions and justifying them by citing institutional constraints and affordances (e.g., technology, resources, timeline) along with heuristics and principles extracted from the learning sciences were used. Furthermore, this approach enabled iteration of the online module by keeping in focus the principles that underlie creating an effective learning experience while also addressing changes to the implementation context.

This paper describes the Lightboard technology and the existing research on Lightboard pedagogy that influenced the design of the learning experience (and remained constant across iterations) in Section 2. Framed by the learning engineering process, Sections 3 and 4 discuss the practice of design decision and justification tracking in the context of the implementation across both iterations of the work. Finally, potentials for the next iteration of the online module and a recap of the practical implications of tracking design decisions and justifications for a team following the learning engineering process to implement learning experiences are discussed in Section 5.

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II. Background: Lightboard Technology and Pedagogical Underpinnings of Lightboard Instruction

A. Lightboard Technology

Creating Lightboard videos involves both hardware and software. The Lightboard itself is a large panel of glass with LED lights around the edges, which causes the markers to fluoresce on the board. A camera captures the instructor and their writing through the glass. The result is luminous writing floating in front of the instructor, who faces the camera while writing/drawing and interacting with the material on the board. Through video capture software, the video is mirror-imaged to correct left-right reversal of the visuals. At the institution, the Lightboard, video and audio capture system, and video workstation are housed in a studio on campus. The goal of the learning experience is to prepare instructors to walk into the studio for the first time and produce a Lightboard video that utilizes established pedagogical approaches that maximize the effectiveness of content delivery.

B. Lightboard Pedagogy

While instructional approaches associated with the use of Lightboard videos are not particularly new, the understanding of best practices associated with creating videos continues to evolve [2] [6] [11]. Despite this evolving understanding, many Lightboard users are mostly unaware of the theoretical and practical underpinnings of effective instruction with a Lightboard. To address this, the learning experience (where instructors are the learners) and the content within the experience (to teach instructors how students learn effectively through Lightboard videos) pull from research that has been done on the impact of Lightboard videos on learning, using the frameworks of Cognitive Load Theory, Cognitive Theory of Multimedia (CTML), and Social Learning Theory [8].

Much of the research about the effectiveness of Lightboard is associated with the fact that Lightboard leverages the natural mode of lecturing at a board (a primary instructional approach) with the key difference—and affordance—being that the instructor is facing the audience while presenting the written and visual content. In this way, Lightboard facilitates teaching as a “dialogue with students,” where students get an unobstructed view of the instructor and can detect contextual and non-verbal communication cues that are missed when the instructor’s back is to the audience. This engagement, via greater visual connection with the instructor (i.e., as posed by Social Agency Theory) [10] combined with the affordances of learning through video (i.e., as posed by CTML) [9], informs a set of Lightboard best practices and behaviors. Focusing on these practices is a crucial way to support and encourage instructors to enact effective strategies on camera.

The technical and pedagogical considerations for creating Lightboard videos described above heavily influenced the design decisions in the first iteration of the learning experience and comprise the content that was kept at the forefront during the second iteration as the implementation context changed. Understanding these key technical and pedagogical underpinnings allowed the team to be well-started to track design decisions and justifications throughout the learning engineering process for this learning experience implementation.

III. First Iteration: MITx Platform, Summer 2020

A. Implementation Context

The three subsections below describe key contextual factors about the learners (instructors), the timing of creating the learning experience, and resources available for designing and building the online module, all of which influenced baseline design decisions for the work.

1) Learners: The target learner population consisted of MIT faculty, instructors, teaching assistants, and other course team members (collectively referenced as “instructors” moving forward in the paper) who are interested in using Lightboard technology as a way to teach sections of content for their courses. Some instructors may have an understanding of instructional best practices associated with Lightboard, but most users are unaware of the theoretical and practical approaches that underlie these practices. While the majority of existing instructors who have utilized the Lightboard since it became available in 2016 were primarily from STEM disciplines (physics, mechanical engineering, chemistry, etc.), the learning experience was designed to be inclusive of any instructor from any department who may want to use the Lightboard.

2) Timing: Given a Lightboard video’s multimedia format and emphasis on the social presence of the instructor in the video, there was increased interest among instructors in using Lightboard during the period of emergency online instruction caused by the COVID-19 pandemic. Supporting instructors with this via an online module was a primary reason the learning experience was created. Although the immediacy of this need drove some decisions, the reality was that the module needed to exist beyond the emergency situation and the content had to remain broadly applicable and amenable to future use beyond its initial implementation. Other initial design decisions were influenced by this context, including ones aimed at addressing the teaching and learning challenges presented by the period of emergency remote instruction. For example, it was conveyed through the content that Lightboard videos do not have to be perfectly “polished” and that producing videos where instructors present authentically and naturally as though giving a live lecture would more closely resemble the in-person teaching that students value but that was lost during remote instruction.

3) Resources: The learning experience was built on the residential instantiation of MITx, a Massive Open Online Course (MOOC) platform based on Open edX. The various technical affordances and constraints of this platform

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influenced the implementation context and shaped many of the design decisions (discussed more in Section 3 B below). For example, the way content could be contained and structured on a given page of the platform influenced how video clips were woven with text. Another major resource was access to the insights and experiences of a Lightboard "power user," a lecturer in physics who has used the technology frequently since 2016. Following a human-centered approach within the learning engineering process [4], the interview with this key stakeholder elicited insightful dos and don'ts of creating videos, how to use the studio equipment, and other tips that were valuable in shaping the language of the content. Additionally, the design team was not able to access the Lightboard studio in person at this time due to pandemic-related restrictions on campus, which limited the ability to include robust images and videos of the studio to accompany content pertaining to the workflow of creating a video in the studio.

B. *Design Decisions and Justifications*

During the design process, the team maintained a design decision tracker in Excel with references to design principles and heuristics backed by the learning sciences to help guide the creation of content, media to deliver the content, sequencing, and interactivity in the course. This tracking system was also used to note contextual and technological constraints to the project, which justified certain specific decisions that were made. Examples of design decisions that were tracked are included in Table 1.

TABLE 1. EXCERPT FROM DESIGN DECISION TRACKER

Design Decision	Justification
To illustrate Lightboard best practices, leverage existing videos featuring faculty in favor of recreating videos, because it is more authentic, engaging, and fosters motivation if the faculty "see themselves" in a variety of video examples.	*Based on principle of learning:* Learners are more likely to be motivated if they feel capable, know when and who in the world carries out such tasks, and have resources that someone in the real world engaging in that task would have [3].
The organization/flow of the learning experience content will be linear: intro → technical specs & process → best practices & pedagogies → use cases → additional resources	*Based on technical constraint:* It's challenging to weave content, as MITx is naturally set up to have a linear approach to content delivery. Weaving can mean making links/jumps to other sections, which should be avoided for a course like this as long term maintenance of such links will become impossible.

Some design decisions were based on research from the learning sciences, such as the first item in Table 1. The team wanted to include video clips of someone exemplifying the recommended Lightboard instructional best practices (as informed by the theoretical frameworks discussed in Section 2 B above) through their on-camera behavior. Ultimately it was decided to use clips from existing Lightboard videos created by instructors who had been early adopters of Lightboard. Informed by design principles related to learner engagement and motivation [3], it was decided that instructors seeing their peers demonstrate Lightboard best practices would make for a more impactful learning experience than alternative approaches, like having members of the design team create these videos.

Other design decisions were based on constraints in the implementation context. As an example, the second item in Table 1 points to limitations with what could be done with the MITx platform. The platform lends itself to learners working through materials linearly. While this addressed the goal of creating a learning experience that instructors could work through, there was the additional goal of instructors being able to go back to the content at any point to reference or refresh on certain tips that would help them while they were creating videos in the studio. It was decided to keep the content in a linear fashion which led to the subsequent decision to create a one-page Quick Start Guide. This was meant as an additional just-in-time resource that was associated with the online module but gave instructors the ability to save or print it out with important reminders from the learning experience.

C. *Design Results in the Implementation*

The first iteration of the learning experience, in MITx, was made available to instructors in August 2020. It is important to note that access to the Lightboard studio at that time was extremely limited due to the pandemic. This resulted in very few new users being able to engage in the Lightboard onboarding process involving this learning experience in the first month or so of implementation. However, the learning experience was released to a preliminary group of testers from the team, which produced qualitative feedback that was used to inform updates to the design decisions that had been tracked. Given that implementation is not limited to a full release or full-scale implementation of a product or solution [4], this "mini" implementation still produced data that led to another round of improvements to the design [7].

The team monitored Lightboard studio usage and planned to continue iterating on the learning experience based on any feedback from the first batch of instructor users. These plans were given a new direction when it was decided the module would move platforms from MITx to Canvas, the learning management system adopted around this time. A key influence in this decision was the absence of data (null results) from the initial MITx implementation around instructor usage. The lack of users, and as a result usable data, indicated a need to pivot to a platform that would lead to increased engagement and a more reliable data stream about that engagement.

IV. SECOND ITERATION: CANVAS PLATFORM, FALL 2021

A. *Implementation Context*

In the fall of 2021, the Lightboard learning experience was transitioned from the MITx platform to the Canvas. This

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constituted a major change in the implementation context, which resulted in updates to previous choices as well as new design decisions. The three subsections below describe changes to the key contextual factors discussed in Section 3 A above (learners, timing, resources), and how design decisions were iteratively updated based on these influences.

1) Learners: The online module on Canvas was equally available to instructors as it had been on MITx, open to any instructor who self-selected to take it. The major change for the learning experience would be how instructors accessed the online module. Adapting it to a new learning management system increased awareness of and lowered the barrier to the learning experience because instructors were already using Canvas for their course sites and therefore did not have to sign up for a different platform (i.e., MITx). Additionally, since the online module became located within a "Canvas Resources for Instructors" public Canvas site rather than its own standalone course, instructors could also encounter it as an option while browsing other Canvas resources.

2) Timing: While both major iterations of the learning experience were due to changes in instructional conditions, the second iteration was specifically due to the rollout of Canvas rather than changes resulting from a global pandemic. This meant new opportunities to update and improve the online module's content. In addition to revisiting the design decisions that had been tracked in the first iteration—to ensure key decisions were maintained during platform transition—there was also the opportunity to revisit and address feedback from testing of the first iteration that had been deferred. For example, content pertaining to the technical workflow of creating a video in the Lightboard studio was improved with photos and video from the real studio as well as more robust explanation of steps. This was possible because the team was able to access the studio on campus this time around and walk through the process, making for more authentic and accurate content compared to the first iteration of the learning experience. Relocating all content onto another platform also allowed for the opportunity to make other edits to improve the learning experience, like being able to easily link to and cross-reference related resources that were already maintained elsewhere on the Canvas resources site.

3) Resources: As stated above, the Lightboard learning experience transitioned from being a standalone course on MITx to becoming a module on an existing "Canvas Resources for Instructors" Canvas site. Working to fit the learning experience within the existing site while still functioning as a "course" resulted in revisiting design decisions pertaining to how the content would be outlined and organized. The goal of the learning experience itself remained aimed at preparing instructors to create Lightboard videos in effective and pedagogically-sound ways, but now the connection between Lightboard videos and Canvas as the instructors' learning management system had to be made more explicit (i.e., Lightboard is one option in a suite of tools, anchored by Canvas, available to help instructors improve and innovate their teaching using available technology).

B. Design Decisions and Justifications

A key practice in transitioning the Lightboard learning experience to a new implementation context was revisiting and updating the design decision and justification tracker started for the first iteration of the module. The details recorded in this tracking system facilitated further decision making about where to improve the design and what aspects integral to the goal of the learning experience to maintain during the platform transition. Part of this systematic approach to tracking design decisions included certain decisions being flagged as priorities to revisit, giving the team strategic entry points to the next round of iteration without rehashing every decision on the tracker. Overall, 8 of the 19 core decisions (just under half) tracked during the design of the first iteration were revisited and improved for the second iteration.

One such prioritized redesign decision was including video clips of instructors demonstrating effective instructional behaviors behind the Lightboard—a key part of the learning experience with a solid justification cited for why this was an approach to delivering content (see Table 1 above). As such, this was not a decision that was going to change during the transition to Canvas. However, the transition afforded the opportunity to revisit which video clips had been chosen and to switch out some of those original clips with videos that even more effectively demonstrated the content or represented more of a variety in disciplines and instructors using Lightboard. For example, a video was added of an instructor who had not previously been featured using the Lightboard during a live Zoom session, which also represented a use case not previously highlighted in the module.

The sequential organization of the content also comprised a key part of the learning experience, but the initial justification for this decision (see Table 1 above) was revisited because MITx was no longer the platform imposing technical limitations on the design. The Modules feature of Canvas lends more flexibility to structure the content as both a linear course for learners to work through as well as a resource where instructors can go for materials on a more ad-hoc basis. This resulted in a revision to the original design decision, including adding more outline/table of contents pages and jump links to facilitate instructors navigating to specific content they may need at any given moment.

C. Design Results in the Implementation

As previously noted, the transition of the Lightboard learning experience from MITx to Canvas entailed the content now being nested within an existing site for instructors that provides resources about Canvas and other tools for teaching and learning. It would now serve the dual purpose of informing instructors how to make effective Lightboard videos and demonstrating and modeling Canvas features and functionality by way of delivering that Lightboard content. The latter of these addressed the need for instructors to experience the more advanced capabilities of Canvas. For example, all video clips were embedded in Canvas pages via Panopto, the main video platform integrated with Canvas that instructors were encouraged to use. Similarly, the few reflection questions throughout the module, originally built using MITx's specific question type functionality, were now built using functionality specific to Canvas (i.e., ungraded surveys).

While data about how instructors have engaged with the learning experience on Canvas is still pending, this latest implementation sufficiently accounts for the new platform's affordances and constraints while continuing to honor the well-justified design decisions made during the first iteration of the learning experience.

V. CONCLUSION AND FUTURE WORK

Working through iterations in the design of a learning experience is a hallmark of the learning engineering process. For the Residential Education team at MIT, two major iterations of a Lightboard learning experience for instructors occurred when the implementation context changed from one platform to another. Further iterations to the learning experience as it currently exists on Canvas are anticipated, particularly when Canvas releases new or updated features, so technological affordances and constraints will continue to shape future iterations. Additionally, with Canvas's data stream, the collection and analysis of data about instructor engagement will drive future iterations. This data exploration will likely serve as the next entry point into strategically revisiting prior design decisions and tracking new design decisions for the third iteration.

For practitioners and teams doing similar design work, it is critical to consider how design decision and justification tracking is a learning engineering practice that can ensure an implementation remains learner-centered and backed by evidence from the learning sciences while still addressing contextual factors. Such a practice directly affects the implementation being worked on and affords the flexibility to navigate changes to that implementation or context should they arise (through tracking). It also allows the design team to examine what worked and what hasn't worked (through revisiting), referring back to why a design element was implemented in the first place (through justifications), and iterating while keeping learners' needs at the forefront (through strategically flagging entry points into the next iteration). While these specific approaches to the practice of design decision tracking may vary depending on a team's context and goals, the Lightboard learning experience case demonstrates how design decision and justification tracking across implementations ultimately helps support instructors in learning to use technology.

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Fostering Communities of Practice: Insights from an Online Educational Robotics Professional Development Pilot

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***Abstract*—Educational robotics is an effective tool for teaching and learning an interdisciplinary STEM curriculum. Yet, traditional teacher education programs often do not cover engineering and technology as part of the curriculum—most often excluding robotics entirely—leaving teachers underprepared for the application of educational robotics in the classroom. To help close this gap, an online professional development program was developed and piloted for robots and curriculum spanning from kindergarten through high school. Preliminary results from qualitative observations and quantitative survey data indicate that this pilot program helped teachers increase interest, self-efficacy, robotics and coding knowledge, and develop a sense of community. Future directions and research based on the results of this professional development pilot are discussed.**

Keywords-educational robotics; professional development; teaching and learning; community of practice.

I. INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) education has become a focus in educational research as well as government agencies setting national agendas in the United States. The National Science Foundation [1] stated that the acquisition of STEM knowledge and skills will be a necessity for participation in a global economy and therefore everyone should have access to high quality STEM education. The National Science and Technology Council's Committee on STEM Education [2] put forth a federal strategy for STEM learning that highlights the need for truly interdisciplinary solutions for learning and skill acquisition, using real-world applications, and combining skills such as critical thinking and problem solving with communication and collaboration. Educational robotics that combines robotic construction with computer science has become an effective tool to deliver interdisciplinary learning that includes both STEM topics, as well as valuable 21st century skills. A meta-analysis of research concluded that educational robotics increases student learning across STEM topics [3]. Researchers studying a range of student ages identified that robotics helped increase student attitudes and positive perceptions of STEM subjects [4][5][6]. When introduced to young students, educational robotics fosters critical thinking and problem-solving skills as well as positive attitudes towards STEM subjects [7][8][9], while robotics for high school students supports college preparedness and technical career skills [10][11][12].

Yet, for all the benefits of educational robotics in the classroom, the inclusion of robotics instruction for formal teacher education is still lacking. Most teacher education programs focus on individual disciplines such as science and math, which leads to teachers being underprepared for incorporating engineering and technology [13]. Teachers who are not formally trained in interdisciplinary STEM feel less confident in those areas and have difficulty making connections across disciplines [14][15]. However, introducing robotics during teacher pre-service education increased teacher self-efficacy, content knowledge, and computational thinking skills [16].

Teacher preparedness for teaching educational robotics can also be achieved through continued professional development as an alternative to pre-service education, which can be slow to change. In the span of K–12 education, there are many different contexts in which educational robotics might be applied and the teachers responsible for incorporating it into the classroom likely have equally varied backgrounds. Professional development programming could become not only an educational supplement for teachers, but a way to develop a community of practice across a diverse group of teachers. Lave and Wenger [17] describe a community of practice as members with shared interests gathering, sharing research and insights to further skills and knowledge, and forming a collective practice in that domain.

The CoP Framework, as described by Smith et al. [20], focuses on three areas: the domain, the community, and the practice. The domain is the distinguishing factor of the group of people. This is the area of knowledge that gives the group its identity. The community is a gathering of people with similar ideas or interests (the domain). These individuals learn and grow as they interact with each other. The practice is engaging with others in the group around the similar topics that constitute the domain. For this paper, the domain is the area of robotics education that brings the community of teachers together. The practice is engaging in this asynchronous flipped classroom course in order to engage with educational robotics and grow their knowledge and experiences together.

Research on virtual robots during the COVID-19 pandemic identified that teachers reached out to virtual communities to problem-solve, suggesting communities of practice may become a more commonplace solution for teachers seeking support for educational robotics [18].

This study describes an online professional development pilot program for educational robotics. The goal was to create a structured series of synchronous learning sessions where teachers from anywhere could join to both develop their knowledge of robotics and computer science as well as interact with other educators using the same robotics. To evaluate the merits of this professional development pilot, participants were asked to participate in a pre- and post-survey that included topics of interest, self-efficacy, robotics and coding knowledge, and community of practice. These topics replicate research by Jaipal-Jamani and Angeli, [16] who used similar survey instruments with a group of 21 preservice teachers. While some questions were adjusted for this context, the goal was to identify if similar positive findings could be identified through professional development.

This paper will be outlined by the following: in Section II, the methods for how the courses were run and data was collected will be explained. In Section III, the results of the VEX 123 and VEX IQ courses will be outlined. The paper will then be concluded in Section IV with a summary of findings, potential limitations of the study, and possible future research.

II. METHODS

As this online professional development pilot was the first of its kind, great care was taken in the design of the materials and delivery with the hope of providing as much benefit to the participating teachers as possible. The courses were designed using VEX Robotics. VEX Robotics is a company that focuses on educational and competition robotics. Their educational penetration offers formal, as well as informal, curricular solutions from pre-kindergarten to collegiate. One course was planned for each level of robot available (VEX 123, GO, EXP, IQ) but each course was designed in an identical fashion. The most productive method of delivering instruction is a flipped blended model. In this model, the instruction is delivered out of the classroom via technology, and the instructor engages the students in activities and feedback during class to enhance understanding. According to Margulieux et al. [19], this is the only model that improved learning outcomes of all surveyed in a meta-analysis. Teachers in the class were assigned content and activities to complete asynchronously between class sessions and the live class sessions were focused on sharing work, asking questions, providing feedback, and building teacher-to-teacher peer relationships. To develop the curriculum for the sessions, a backwards design was utilized. Clear, measurable learning objectives were created for each week's class and content was then curated for each objective. Teachers were provided with a structured syllabus that outlined each week's work, including the learning objectives, list of asynchronous lessons to complete, and the activities to complete prior to class. Lastly, at the end of the course, teachers were asked to create an implementation plan for how they would use educational robotics in their specific context. The goal of this assignment was to use all the previous lessons and apply them to a practical project that would help teachers translate what they had learned into their classroom.

Synchronous class time was designed to provide teachers with useful feedback, given the material and activities completed outside of class. When possible, class time was spent having teachers share what they created outside of class with their peers, providing feedback on work teachers did, answering specific questions, fostering teacher-to-teacher sharing and feedback. While a community of practice cannot be forced, it can be encouraged by bringing together teachers around a shared domain and providing opportunities for them to learn, build relationships, and share knowledge. Not only were teachers collaborating in the face-to-face synchronous sessions, but they were also encouraged, and asked as part of the weekly requirements, to post in a professional learning community called VEX Professional Development Plus (PD+). Posting on this collaborative platform was intentionally built into the syllabus and course requirements to allow teachers to learn and grow together to further build the community of practice.

Teachers were asked to complete a pre-survey prior to the first session and again at the end of the course. The survey included instruments like those used by Jaipal-Jamani and Angeli [16] on teacher interest in STEM, robotics self-efficacy, robotics and coding knowledge, and a new instrument on community of practice. Sessions were recorded and qualitative observations were recorded by the professional development leads.

For each of four courses run, the professional development lead made observations of the synchronous class sessions on themes of self-efficacy, persistence, content knowledge acquisition, and community of practice. Class recordings were also used (with permission) to review conversations on these themes. This qualitative data gives additional insight into the performance of this educational robotics professional development pilot, especially when considered in conjunction with the survey results. There were 11 teachers participating across all four courses, and two courses are described in depth here.

III. RESULTS

A. *VEX 123 Course*

The VEX 123 robot and curriculum is intended for grades K–2, so the participants were early elementary school teachers. These teachers did not express any concern about using 123 in their classrooms. They all commented that the product was easy to use, and the resources provided by VEX (STEM Labs, Activities, VEX Library) were all very helpful. Most of the questions in the class revolved around how to get more out of 123 with their students. For example, how can I use 123 in more classes, how can I get more time for STEM and Computer Science, how can I work with more teachers? The class shared many strategies to address these issues, so the teachers did feel more confident about those things at the end of class.

Concerning content knowledge, the participants demonstrated increased knowledge in the concept of coding as a playground, meaning that coding should be a fun and expressive medium for students. Coding should not be just viewed as workforce development. The participants also demonstrated increased knowledge in pedagogy, specifically, the perils of utilizing unguided constructivism. A great deal of time was spent discussing the philosophical underpinnings of the curriculum. The teachers felt that this was empowering for them to create their own curriculum for their students.

It was consistently emphasized during class that the class belonged to the teachers, and they could take the class into any direction that was most helpful for them. This helped to foster a sense of ownership for the participants. Teachers used the professional learning community site to share their weekly assignments. By the end of the course, the teachers were not only communicating on that community forum, but on twitter as well.

B. VEX IQ Course

The IQ robot and curriculum is designed primarily for middle school students, so the teachers in this course were grades six through eight. Experience levels differed between teachers. There were some teachers who were unfamiliar with IQ but had experience with 123, GO, or even V5. For those who did not have experience IQ, they were unsure if they were going to be able to build and code a BaseBot, for example, if they had only done 123 or GO. Once they followed the build instructions for the BaseBot and then dragged in one [Drive for] block to get the robot moving, they could see that the barrier of entry was not as high and did feel more confident about building and coding.

Participants not only increased knowledge about building and coding, but about the curriculum as well. Most participants did not know how to get started with IQ. They were unaware of the STEM Labs or how the curriculum was designed. The biggest challenge to overcome was explaining how this could look and run in a classroom setting, since the STEM Labs are designed to be competition focused.

Throughout the course, participants were encouraged not only to ask questions in the community, but also to share ideas they are currently using in their classroom, as well as images of this implementation. Teachers who had less experience gave feedback that they found it extremely helpful to be able to visualize how certain aspects of IQ were being implemented in a classroom. Posts from the professional learning community forum were shared during class in order to emphasize how useful it can be to not only talk to the VEX Experts, but also to other educators. Many participants realized they were from the same state or close by and noted to either visit each other’s schools or collaborate outside of class. It was also nice to see that some educators in the class had experience, while others did not, and those that did shared how they use IQ in their class, either through stories, images, or videos. This helped the participants who did not have experience yet with IQ.

C. Teacher Surveys.

The surveys were voluntary, and ten teachers completed the pre-survey instruments. However, only four teachers also completed the post-survey, limiting the comparison to a very small number of participants. Even though there were four courses, only four teachers from the 123 and IQ courses completed the post-survey, so those are the two highlighted courses in this paper. As a pilot, this data is still meaningful to review, especially in conjunction with the observations from the courses. The Likert scale responses were re-coded to numeric values in order to calculate a mean score for each instrument.

The results in Table 1 show increased total mean scores for each of the instruments used. Participants indicated small increases in interest in STEM subjects. The robotics self-efficacy instrument provided a scale from 0 to 100, and all respondents reported an increase of at least 10 points on that scale. Robotics and coding knowledge only saw a small increase. Follow up investigation on this instrument may be warranted to determine if participants truly did not feel they increased their knowledge, or if the Likert scale options limited the expression of their self-assessment. The increased mean results for the community of practice instrument were also a promising result that aligned with the qualitative data from the courses. It is noted that participant 1 is the only teacher to have a small mean decrease in CoP. This could be a mistake in filling out the post-survey, or intentional. One of the CoP questions was, “When it comes to teaching with educational robotics, I feel that I have colleagues and friends with similar interests.” This individual may have felt after learning more about robotics in the course, that their colleagues and friends do not have similar interests in robotics, and therefore gave this question a slightly lower rating. Overall, even though it is not clear as to why participant 1 lowered their average score on CoP during the post-survey, out of the four teachers who participated (including participant 1), the CoP total mean increased from 3.94 to 4.38.

IV. CONCLUSION

While the small number of responses to both the pre- and post-survey limit the conclusions that can be drawn, the results do provide positive indications that this online professional development program could help teachers in meaningful ways. The observations from the online classes and survey results both show increases in teacher interest, self-efficacy, knowledge, and sense of community. This online professional development pilot also provided meaningful lessons in the design of the courses. The flipped-blended format worked very well to engage educators and focus class time on what the teachers wanted to cover. This format also increased the amount of teacher-to-teacher interaction during the online synchronous classes. However, one lesson learned was that teachers may be teaching with multiple different robots and therefore wanted to attend multiple courses, which was limited by their concurrent

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timings. Another lesson learned was to offer the surveys in such a way as to maximize response rates for both the pre-survey and post-survey. Furthermore, a closer inspection of the robotics coding and knowledge question format may be warranted to ensure teachers have response options that allow them to adequately reflect their self-assessed knowledge.

The community of practice theme is especially encouraging from these results. Future research that follows the continued interactions of teachers beyond the professional development course could help to evaluate if the sense of community fostered in this program continues to develop over time.

Teachers who use educational robotics in the classroom to teach an integrated STEM curriculum likely have a wide range of prior experience and education specifically in this area. Providing teachers with support through continued professional development can help overcome the lack of robotics and STEM education in formal teacher education programs and meet teachers right where they are. Online professional development is a promising solution not only for the flexibility of content delivery and format, but also to bring together teachers from different locations and learning contexts. Facilitating a community of practice that can continue to support teachers long after the conclusion of the professional development course is a valuable outcome for the program. Even though again, the sample size for the pilot was small, the experiences and successes of teachers using educational robotics in the classroom should be shared broadly to benefit the applied pedagogy and implementation of STEM curriculum for teachers and students alike. There are many online courses using a flipped classroom model currently in the field of education, but many of those courses are not using robotics. Even if the sample size could be unreliable to come to any firm conclusions, sharing experiences and observations about the courses in general can benefit the field simply by example.

TABLE I. MEAN SCORES FOR ROBOTICS SURVEY INSTRUMENTS.

Participant	**Interest**		**Robotics Self-Efficacy**		**Robotics & Coding Knowledge**		**Community of Practice (CoP)**	
	Pre	***Post***	***Pre***	***Post***	***Pre***	***Post***	***Pre***	***Post***
#1	5	5	62.5	82.5	4	4	5	4.25
#2	4.35	4.65	77.5	87.5	4	4	3.75	4
#3	4.5	4.95	60	72.5	4	4	3.5	4.5
#4	4.1	4.95	90	100	4	5	3.5	4.75
Total Mean	4.49	4.89	72.5	85.63	4	4.25	3.94	4.38

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Multimedia Learning Principles and Instructional Design Among Teachers

A Pilot Study

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***Abstract*—An online survey of 112 educators who teach in a variety of K-adult settings explored the extent to which teachers understand and implement two Cognitive Theory of Multimedia design principles known to reduce extraneous cognitive processing into their electronic slide presentation (ESP) designs. Results indicate that although educators regularly design their own slide decks, most participants have low knowledge of how or why they should design coherent slide decks that do not include redundant information. Results also show the instrument questions should be refined and clarified.**

Keywords—Electronic Slide Presentations; Cognitive Load Theory; Cognitive Theory of Multimedia Learning; Coherence Principle; Redundancy Principle

I. INTRODUCTION

Teachers often create their own Technology-Enhanced Learning (TEL) materials [1]. PowerPoint® software is used extensively in both virtual and face-to-face learning environments [2][3]. It is possible that the quality of teacher-created TEL affects learning outcomes. Yet, it is unclear whether educators implement proven pedagogical practices in the design of instructional slides [4][5]. The application of the Cognitive Theory of Multimedia Learning (CTML) principles to Electronic Slide Presentations (ESP) has been proven to improve student learning in higher education [6]-[10].

The completion of a pilot study is no guarantee of the success of a main study, but it can result in improvement of the instrument [11]. This pilot was conducted to examine educators' understanding of and adherence to two evidence-based cognitive principles shown to mitigate extraneous mental processing (coherency and redundancy) in their design and use of ESP slides by seeking to answer: 1) To what extent do educators have a working knowledge of the CTML principles of coherency and redundancy? and 2) To what extent do educators apply the research-based multimedia principles of coherency and redundancy in their electronic slide design?

In this paper, the CTML theory and principles under investigation are briefly described in Section 2, and Section 3 explains the method and procedure. Results are reported in Section 4. Finally, conclusions and suggestions are presented in Section 5.

II. LITERATURE REVIEW

Mayer's development of the CTML principles grew out of Cognitive Load Theory (CLT), which is based in part on Working Memory (WM) theory [12]. New information (regulated by a central executive component) is perceived through the ears (phonological loop) and/or the eyes (visuospatial sketchpad) [13]. This model is a central tenet in both neuroscience and cognitive psychology [14].

CLT claims three types of cognitive load can interfere with learning: intrinsic, extraneous, and germane [15]. Intrinsic load is caused by the complexity of the information to be learned. The number of interacting elements dictates complexity, over which the instructor has no control [16]. However, the instructor can influence extraneous cognitive load, caused by items and activities that distract a learner from the task [17][18]. Germane cognitive load redistributes and mediates the cognitive load required to integrate new information into long-term memory [17].

Mayer applied the CLT model to multimedia learning and developed the idea that people learn more from both pictures and words than from words alone [17]. CTML currently proposes fifteen multimedia principles that instructors can use to improve learning [12]. This pilot study focused only on extraneous load. Within that category, only two multimedia principles were investigated: redundancy and coherence. The essential idea is to help people learn more deeply by presenting information in a way that does not cause the visual or auditory channels to compete for cognitive resources [17].

The redundancy principle implies people will learn more easily from a slide with a combination of graphics (visual) and narration (auditory) rather than a slide with graphics (visual), narration (auditory), and written text (both visual and auditory). If a learner's attention is divided between two things requiring visual processing (graphics and text), comprehension of both items is reduced [19]. Text on a slide identical in meaning to the narration is redundant and causes learner distraction [20]-[22].

The coherence principle states that people learn better when the information presented directly pertains to the topic [18]. Unrelated information causes distraction and reduces learners' ability to process new information. Moreno and Mayer [23] found that unrelated background music played simultaneously as narration caused competition in the audio channel of working memory and reduced learning.

III. METHOD AND PROCEDURE

Descriptive data were collected through an exploratory web-based quantitative survey by contact with the researcher's schools, social media, and professional educational organizations. Through convenience and voluntary response sampling, educators were recruited as participants from a variety of virtual and face-to-face school settings in North America. The software Qualtrics® collected demographic data and Likert scaled responses concerning teacher knowledge and implementation of the coherence and redundancy principles to reduce extraneous cognitive load. Each research question was addressed three times. The software SPSS® (Statistical Package for Social Sciences) was used to analyze the results. Answers that positively reflected the principle were coded with a "1" and interpreted as high knowledge of the principle. Incorrect responses and I do not know responses were coded with "0" and interpreted as low knowledge of the principle.

Copyright-free images of possible ESP slide decks were included to assess knowledge of the principles. Figure 1 shows the two options for the coherence principle. The question was: "From which of the following two slides will student learn more deeply?" The slide option to the right contains an interesting but unnecessary graphic with extraneous text. Figure 2 shows the choices for the redundancy principle. The slide option to the right includes text redundant to the narration.

A separate group of questions assessed teacher implementation of the principles in ESP deck design. Participants responded to questions with four possible responses: Always, Most of the time, Sometimes, and Never. Answers that showed adherence to the practice of implementing the multimedia principle were coded "1," while those that did not indicate adherence to the principle were assigned a score of "0".

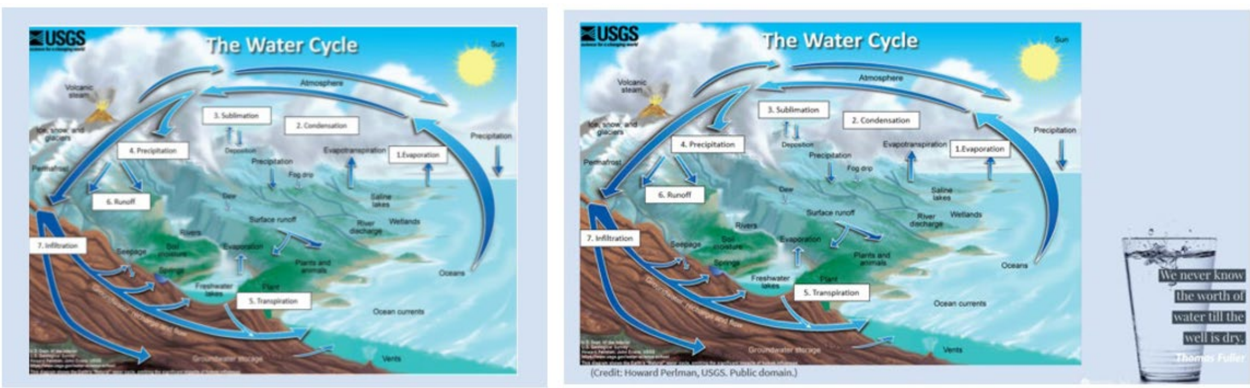

Figure 1. Knowledge of the coherence principle choices.

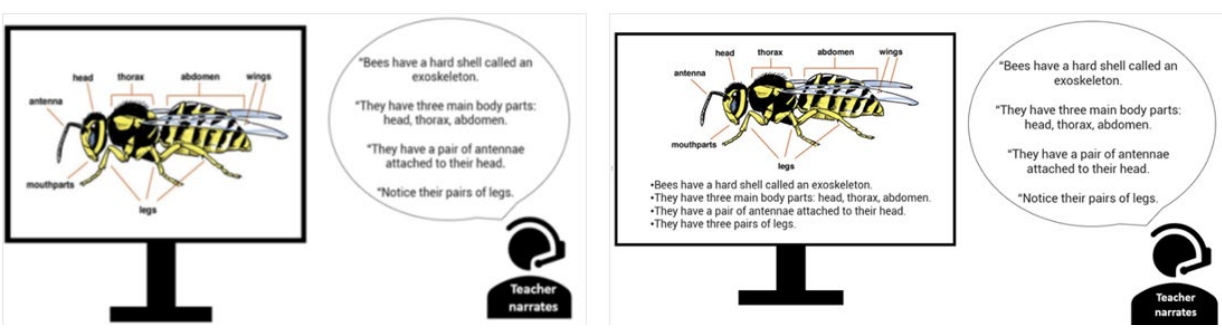

Figure 2. Knowledge of the redundancy principle choices.

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IV. RESULTS

Professional teachers (n = 112) who instruct students in different levels, environments, and content areas who use PowerPoint® or a similar presentation software tool (elementary school, n = 48; secondary school, n = 44; post-secondary school, n = 20) responded to the survey. The mean age of participants was 43.98 years, and the average of all respondents' teaching experience was 15.76 years. In all, 72 (64%) of participant educators used ESP software face-to-face in a brick-and-mortar classroom; 44 (39%) in an online asynchronous environment; and 64 (57%) used ESP software in distance, online, or virtual synchronous classrooms.

A. Knowledge Questions

Table 1 presents the responses to the coherence principle questions. Overall, participants appear to have inconsistent knowledge levels of this principle (M = .59, SD = .255). About half (n = 59, 53%) correctly identified the definition of the principle. A majority (n = 78, 78%) recognized that extraneous background music can be detrimental to comprehension, but only about one third (n = 43, 38%) drew the same conclusion about unnecessary graphics. Most participants, however, could identify a visual example of a more coherent slide *(*n = 86, 77%). Several respondents indicated they did not know the correct answers (34% for question 1; 21% for question 2; and 47% for question 3).

TABLE I. KNOWLEDGE OF COHERENCE

Knowledge of the Coherence Principle Questions			
Question	*Response*	*N*	*%*
Students learn better when interesting but extraneous graphics are excluded.	True	43	38%
	False	35	35%
	I do not know	34	34%
Students learn better when pleasant but unnecessary background sounds are included.	True	10	9%
	False	78	78%
	I do not know	24	21%
The coherence principle states to keep students' working memory from being overloaded, we should eliminate extraneous material from our presentations.	True	59	53%
	False	6	5%
	I do not know	47	42%
From which of the following slides will student learn more deeply? (Water cycle images)	Coherent image	86	77%
	Incoherent image	26	23%

Table 2 presents the responses to the redundancy questions. Fewer participants correctly identified the redundancy definition (n = 19, 17%) than the coherence definition. A slight majority (n = 68, 61%) recognized learning is improved when narration is conducted along with a graphic rather than printed text. About half of the participants chose the sample ESP slide with no redundant element (n = 57, 51%). A high proportion of participants indicated low knowledge by choosing "I do not know" as a response.

B. Adherence Questions

The data indicate that educators' slide design slightly adheres to the principle of redundancy (M = .52, SD = .315). However, two questions were criticized for assuming educators would show a slide with full paragraph of text. The first was "When showing a slide with a full paragraph or more of text, how often do you read the paragraph to the students?" and the other was, "When showing a slide with a full paragraph or more of text, how often do you give students time to read the paragraph in silence?" Therefore, those questions are not included. Only one question, "How often do you combine an image with a full paragraph or more of text?" (M = .71, SD = .457) is measured. Most participants (n = 79, 70.5%) were rated as having high adherence to the redundancy principle in this question.

TABLE II. KNOWLEDGE OF REDUNDANCY

Knowledge of the Redundancy Principle Questions			
Question	*Response*	*N*	*%*
Students learn better when a slide has all three elements: written text + graphics + teacher narration.	True	90	80%
	False	13	12%
	I do not know	9	8%
Students learn better when narration is accompanied by graphics rather than when the teacher narrates the printed text on the screen word-for-word.	True	68	61%
	False	19	17%
	I do not know	25	22%
The redundancy principle states presenters should not read their slides aloud because words we read are processed in both auditory and visual channels, which can cause students to comprehend less.	True	19	17%
	False	33	29.5%
	I do not know	60	53.6%
From which of the following slides will student learn more deeply? (Bee images)	Nonredundant image	57	51%
	Redundant image	55	49%

V. CONCLUSION

Results of this pilot study reveal an inconsistent working knowledge of and adherence to the CTML principles of coherence and redundancy in educator ESP design. This lack of knowledge is concerning considering teachers are increasingly creating their own TEL materials, including slide presentations.

The large proportion of "I do not know" responses to knowledge questions may indicate a need for professional development. However, the data indicate some educators may be more intuitive about identifying higher quality slides without having explicit knowledge about definitions. It may be worthwhile to evaluate teacher-created slide decks and compare the results with teachers' perceptions of their adherence to the principles.

One purpose of this study was to gather information to develop a base of understanding about teacher practices before determining if applying CTML principles to ESP decks will improve student learning. Unfortunately, the results were limited because of unclear question wording and restricted answer options. Future studies should include clearer questions and use a Likert scaled response system.

Other suggestions for future research are to determine training requirements for virtual teachers, limit participation to K-12 virtual learning environments, for which there is a scarcity of studies, to investigate differences in terms of instruction for different age groups, and to expand the number of CTML principles to include contiguity and signaling, which are also used to reduce extraneous cognitive processing.

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Developing Instructor Training for Diverse & Scaled Contexts: A Learning Engineering Challenge

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***Abstract*— Learning engineering provides both a practice and process for solving educational challenges. While the circumstances of each challenge require a unique application of learning engineering, the learning engineering process was designed in such a way to provide guidance across a broad range of contexts. In this paper, the learning engineering process is articulated from the perspective of the developers of online courseware used in higher education. Within this use-case, we exemplify how an initial learning engineering process for the creation of the courseware provided a starting point for iteration, and in this instance, the beginning of an entirely new process on instructor enactment of that courseware. Whereas the initial challenge was to develop the courseware environment, this emergent challenge now focuses on understanding and addressing contextual factors that affect the successful instructor application of the courseware learning environment at scale.**

Keywords-learning engineering; learning engineering process, instructor training; teaching and learning; learning technology; courseware.

I. INTRODUCTION

Learning engineering is defined by the IEEE IC Industry Consortium of Learning Engineering (ICICLE) [4] as “a process and practice that applies the learning sciences using human-centered engineering design methodologies and data-informed decision making to support learners and their development.” Learning engineering is an interdisciplinary practice that incorporates the learning sciences, data science, curriculum research, game design, and more, providing an infrastructure for design research, analytics, and iterative improvement [2]. A learning engineering process model was first developed through initial work in the ICICLE design special interest group [6] with later iterations discussed herein [7]. The learning engineering process model is cyclical in form to reflect the concurrence of work required and the constant iterations that occur in trying to solve any educational challenge. This learning engineering process itself is broadly described as the applications for its use are equally varied. There are many types of educational challenges to be solved and as many groups working to solve them. The learning engineering process provides an organizational workflow that any person or team can apply to their challenge. As shown in Fig. 1, the challenge to improve learning or learning environments is at the center of the model. Investigation, creation, and implementation are all connected in the process of designing and enacting the solution to this challenge. Yet each of these phases of the cycle can also inform the challenge and solution in their own iterative cycles. Lastly, the context, learners, and team all contribute to variations in how challenge solutions can be scaled or not depending on the almost limitless varied settings such solutions might be deployed.

Figure 1. The learning engineering process (CC by Aaron Kessler).

This process can be broadly illustrated through the example of courseware development at Acrobatiq (Fig. 2). The challenge at the center of the learning engineering process was to create courseware that applied established learning science research to provide an effective digital learning environment for students. The context for this challenge was shaped by Acrobatiq’s origins from Carnegie Mellon University’s Open Learning Initiative and the research in online learning established there (e.g., [8][9]. The goal was to apply that research to a courseware environment that could be used by students across higher education institutions at large. The team consisted of learning

Figure 2. The learning engineering process with the central challenge of creating online courseware.

engineers, software engineers, subject matter experts, project managers, and data scientists. This team collectively contributed to the creation phase of the process. During this phase, the courseware platform and content were created—which consisted of many iterative cycles of design, development, and data instrumentation.

Once ready, the process moved on to the implementation phase wherein the courseware learning environment was used by instructors teaching at community colleges and four-year institutions. Data were collected by the platform as students engaged with the courseware, and these data were then analyzed during the investigation phase. The data analysis of this investigation stage provided examples of effective learning methods such as adaptivity [16] and replication of findings of previous research on the learn by doing method [17]. The investigation phase also uncovered areas in need of improvement, which created additional iterations of the learning engineering process. For example, data analysis showed low student use of the adaptive activities across course subjects and educational institutions. Identifying this issue initiated an iterative improvement cycle wherein a change was made in the location and delivery design of the activity. This change was then re-implemented with students, and further data analysis showed this solved the challenge, and completed that iteration of the original learning engineering process [15]. It should be noted that these analyses and iterations did not occur one at a time, but rather as concurrent processes.

Yet other investigations of the courseware usage identified a new challenge altogether. An analysis of the same Probability and Statistics courseware used across a state system of community colleges and universities identified that different instructor implementation policies and practices affected student engagement with the courseware [18]. This analysis revealed the need for a new learning engineering process where the challenge was no longer developing effective courseware, but rather facilitating the instructor's application of the courseware across a large scale of unique learning contexts, as seen in Fig. 3.

When we consider the challenge that no two educational settings are the same, it becomes clear that the instructor's application of any learning resource, technology, or intervention could result in varied outcomes across settings. Successful practices in one specific learning situation may not be successful in a different environment. This work seeks to accomplish two goals. The first is to show how multiple learning engineering challenges and processes can evolve from a single original challenge. The second is to focus on the contextual factors that contribute to how instructors enact any learning technology, resource, or treatment and how the learning engineering process can be applied to solve this challenge. The courseware example highlights the learning engineering process used to design a solution to better train instructors in a scalable way, with the goal of supporting effective implementation of the courseware in diverse and distributed environments. Situating this case in cycles of the iterative learning engineering process exemplifies how one cycle of work can result in clear points of identifying and/or redefining the central challenge addressed through the learning engineering process.

II. The Learning Engineering Challenge: Context-Specific Training at Scale

Every opportunity a student has to learn is one in which a learning experience—including an instructional plan—was purposefully designed and implemented. Whether this occurs in a traditional classroom between a teacher and students, an after-school program, or an online training for lifelong learners, each learning interaction is an implementation of a designed learning experience. The implementation of an instructional plan has the potential to drastically impact how students engage with the learning resource and develop the knowledge at the core of the learning experience. Beyond that, it can also impact the way in which students are able to demonstrate their understanding through assessments and activities. Recent examples of research on digital learning resources showcase the crucial role of the educator for the implementation of technology in the classroom. A study investigating the teachers' role implementing a cognitive tutor for math education for fifth to eighth graders identified different patterns of teacher/student/cognitive tutor interactions that could impact student performance in computer-directed learning environments [5]. Research on an instructor's implementation practices of adaptive courseware in higher education showcased how specific changes to course policies and teaching practice strongly impacted student engagement and exam scores [3].

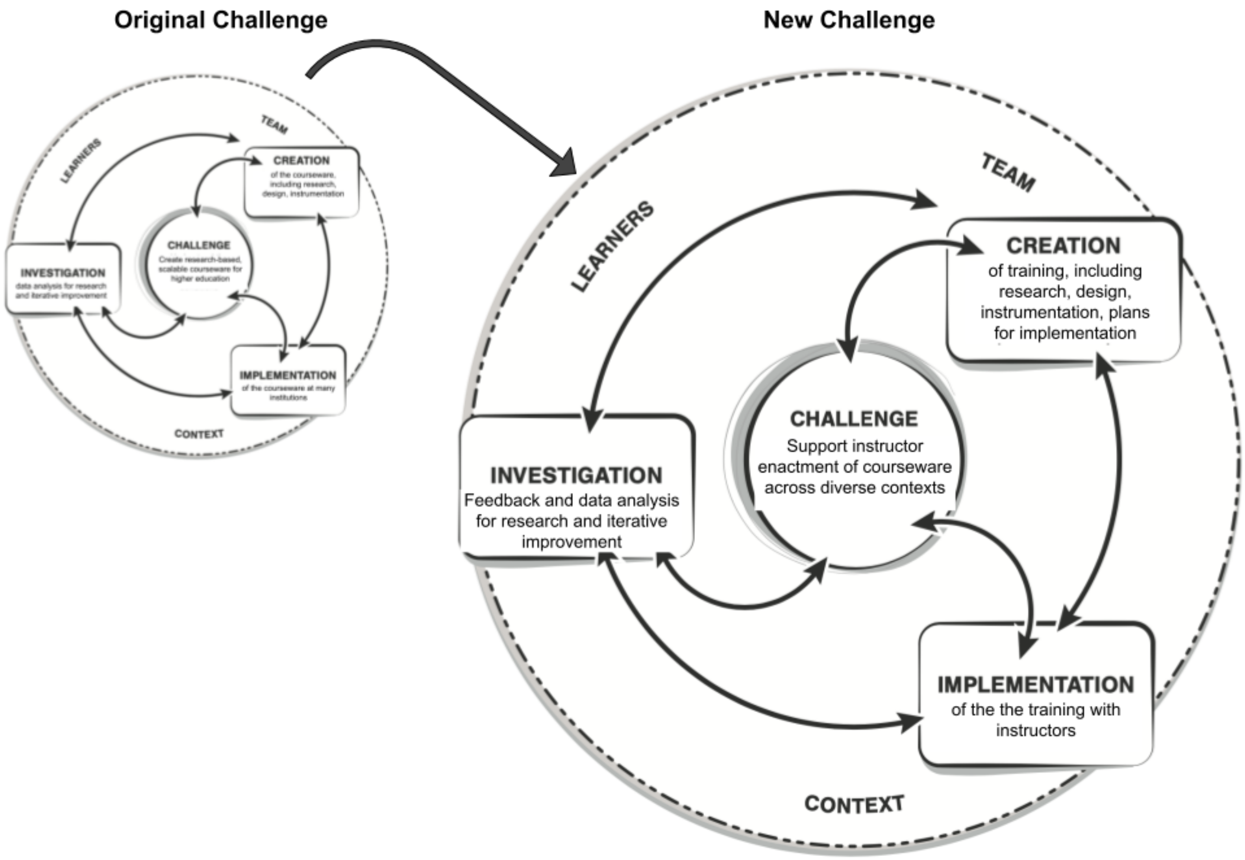

Figure 3. The original challenge of creating courseware leads to a new challenge—supporting instructor enactment of courseware across diverse environments.

The discussion of implementation is not new, with efforts to define and describe its importance in educational research going back decades [1]. Implementation—and the level of fidelity to the intended implementation plan—is a rigorously applied practice in the healthcare field where adherence to a implementation of a treatment is highly relevant to outcomes, yet historically has been less frequently applied in education to evaluate the efficacy or effectiveness of an educational treatment [11]. This concept of implementation is relevant at its most basic level to the use of courseware as a learning resource in the classroom: in order to help students achieve the benefits of the courseware (i.e., learn by doing or adaptivity), they must actually *use* those features. However, unlike the example of controlled lab experiments in the healthcare field discussed by [11], all educational natural learning contexts will have variability that cannot fit a single prescribed implementation plan. The learning engineering process can help to address this challenge by unpacking the contextual factors surrounding the implementation of courseware at scale.

Before continuing the unpacking of this learning engineering challenge, an issue of language must be addressed. As described in the literature above, implementation as a term is commonly used to refer to the application of a plan or treatment either in a controlled experiment or natural learning settings. However, this same term is used as the label for the stage of the learning engineering process in which the solution is deployed. In this work, the challenge of the learning engineering process (the implementation of the courseware across varied educational settings) and the implementation stage (in which the solution to this challenge is implemented) will become easily confused. Therefore, in this work, implementation will refer to the learning engineering stage, and the central challenge will be referred to as the instructor's application or enactment of the courseware.

A. Challenge Context: Variation in Instructor Setting

In the original learning engineering process discussed above, the central challenge was to develop courseware that could serve students and instructors in a wide variety of educational settings. Yet the variation in the implementation phase of the learning engineering process—wherein instructors utilized the courseware in their teaching practice in widely different ways—resulted in significant differences in student engagement and outcomes. This realized variability presents the opportunity for establishing a second challenge, not about the development of the courseware

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itself, but rather the application of it in the classroom. Given that the courseware was designed to be agnostic to setting, it cannot be differentiated for each use-case. Therefore, a potential set of solutions to this challenge required exploration outside of the technology itself and as such involve a new learning engineering process described in greater detail below.

Part of the learning engineering process is the basic principle that learning itself is situated within specific contexts. Consider first the complexities educators are faced with for teaching and learning. The courseware as a learning resource may be a new environment for instructors compared to traditional textbooks, or even etexts. In addition to the courseware, instructors likely also use a learning management system and other teaching and learning tools that make up the learning ecosystem for a course. Teaching models (such as traditional, blended, flipped-blended) vary by instructor and interact with teaching modality, which has expanded from face-to-face to include hybrid and fully online learning modes with increasing frequency. These options for teaching models and resources are further complicated once considering their interaction with the specific group of learners being instructed. The number of students as well as their characteristics all contribute to the unique context in which an instructor applies their instructional plan. The instructor's use of courseware (designed to be context agnostic) within varied and unknowable settings is the context for the second learning engineering challenge (Fig. 3).

B. Designing a Solution

As seen in Fig. 1, the design phase of the learning engineering process encompasses several tasks necessary for the development of the solution. The relevant research from the learning sciences should be consulted for the design and development of the solution, with data instrumentation incorporated into both of those tasks. Finally, plans for the implementation of the solution are created [13].

1) Design

One designed solution to the challenge of effectively utilizing courseware across many diverse settings is instructor training and support. While there could be any number of other solutions, the influence of instructor choices on student participation and outcomes is an established relationship that can be leveraged toward optimum courseware usage, and the instructor is also able to adjust enactment plans to account for their specific setting of teaching and learning. Before beginning to design and develop this instructor training and support solution, the existing research and knowledge base on instructor policies and practices that are beneficial engagement and outcomes should be consulted. Research can surface a set of practices to consider recommending for instructors—and sometimes a set of practices to avoid. For example, the teaching model (traditional, blended, flipped-blended, etc.) is known to influence student outcomes [10], and therefore is a factor to consider for the application of courseware as the learning resource for a class. Simply using the courseware and completing the formative practice garners benefits for students, so assigning completion points as part of the overall course grade could become a recommended practice [3]. Another strategy to recommend could be to use the data from the instructor dashboards to facilitate interventions between instructors and students or help tailor additional instruction around content students struggled with. A community college case study of instructors using courseware identified that the data dashboards helped identify at-risk students and facilitated a flipped-blended model for in-person and remote learning [14]. Research on successful practices for teaching and learning with digital resources can provide a starting point for the design and development of a solution [13][7].

2) Instrumentation

Instrumentation in the learning engineering process is when data collection is designed, developed, and implemented. This instrumentation step is part of the creation phase because preparing for what data will be needed for analysis and how that data will be collected must happen concurrently with the design and development of the solution. While the courseware collects data as students are learning, this does not help address the challenge of assisting instructors' use of courseware within their specific teaching and learning setting. Therefore, gathering data to explore and understand their situated learning environment should become part of the solution. The focus on instructors and their needs for teaching when instrumenting a solution is aligned with the human-centered approach of learning engineering. "Human-centered engineering design means designing from the perspective of humans who will be interacting with implemented designs" [12, p. 83]. Identifying core variations in teaching and learning that instructors have to navigate in order to instrument and implement the solution maintains the instructors at the heart of the solution.

Instructors will need to identify factors that contribute to how they might enact this learning resource. This could include identifying the teaching model, modality, number of students, student characteristics, course category (major/non-major, elective, required, etc.), and graded components of the course. One avenue for standardized data collection would be surveys for the instructor to complete prior to receiving their training materials (the solution in development). These factors all contribute to how the courseware could be most successfully utilized and, therefore, are necessary for instrumentation as inputs for tailoring training for instructors.

Instrumentation should also include gathering success criteria and the subsequent data necessary to determine if those success criteria were met. This type of instrumentation can be easy to overlook but is key to maintaining a cohesive vision for the goals of using courseware as a learning resource across all stakeholders involved. This also means that this instrumentation will need to consider several distinct groups of stakeholders. To design for instrumentation at different levels, the first step is identifying the relevant groups. Students are the primary users of the courseware, as it is their learning resource, and therefore defining what success looks like to them is key. Depending on the situation, this could range from simply engaging with the courseware

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to increased learning outcomes on assessments. Also consider the difference between what students would identify as their successful use of the courseware versus what the instructor would define as student success. The instructor's goals likely would include success criteria for students—such as improved grades—but may also include goals for themself such as shifting the teaching model, identifying and intervening with at-risk students, or tailoring instruction based on data. There may also be additional stakeholders further removed from the active use of the courseware who have a vested interest in its use and therefore additional success criteria, such as administrators. Their goals may be more broadly related to success and retention metrics. Identifying each group of stakeholders for the courseware and their goals allows for the instrumentation of data collection to determine how those goals are being met. Without this instrumentation planning, design, and development, there could be a lack of clarity as to whether the courseware was successfully applied in a specific context to meet specific goals and, furthermore, what iterative improvements may be needed to meet those goals in the future.

3) Plan for Implementation

With the research base established and instrumentation stakeholders understood, the design and development work can move out of initial stages and continue concurrently. The challenge of how to train and support instructors to implement courseware effectively in incredibly varied settings requires a solution that can address these situational factors (as many as feasible) in a scalable way. As courseware is designed as a learning resource for students, training must be designed as a learning resource for instructors. Each major contextual factor identified could be addressed as a topic with successful practices established in educational research combined with case study successes to address common variability in each topic. Preparing for known variations in teaching environments can provide a stand-alone resource, but planning for unanticipated cases should also be part of the solution design. Direct instructor training would be beneficial not only for identifying these special cases, but also to execute the instrumentation plan described for collecting data on context and stakeholder goals. Furthermore, just as instructors need to tailor their use of courseware depending on whether they have 20 or 200 students, so too would the instructor implementation training and support plan need to adapt depending on the number of instructors. Designing different training implementation plans depending on the number of instructors and modality of training is another component of the creation phase.

C. Implementation and Investigation

Once the instructor training solution has been designed, instrumented, and developed, it is time to implement it with instructors. The implementation of this solution may begin with a few instructors as a pilot or with a large number of instructors if delivery at scale is possible. No matter the scale, data collected from instructors on their unique teaching factors will begin to inform the investigation of the solution. For example, an instructor teaching a traditional face-to-face semester course and an instructor teaching an asynchronous online course will both experience the training solution and use it to attempt to optimize their application of the courseware in their unique setting. Combining the data collected from their teaching context with the student engagement and outcome data collected from the courseware will begin to inform how successful the training solution was in supporting instructors. Additionally, the contextual factors provided by instructors would inform new content or changes to the training solution to incrementally increase the factors covered, iteratively improving the solution. Feedback from instructors on success metrics would also surface information in the investigation phase of the learning engineering process that could lead to new instructor enactment suggestions in the training. Ideally, each implementation of the training would provide data to inform further improvements to the solution, which would hopefully continuously improve instructor use of courseware in their educational context for the benefit of student learning.

III. Conclusion

Learning engineering as a process is used in many different contexts to solve many different educational challenges. However, it is unlikely a challenge would be perfectly solved after one single cycle of the learning engineering process. Instead, the process is designed and intended to support many iterations of the process to continuously improve the solution, while also being aware that sub-cycles or entirely new but related learning engineering challenges may arise. Clearly identifying each educational challenge at the center of each learning engineering process and how multiple separate or sub-cycles relate will benefit the entire learning engineering team tasked with solving the challenge(s) most effectively.

The example of how multiple related learning engineering challenges can develop expressed here was chosen to highlight a related challenge often overlooked: the highly varied educational settings within which educational technology and interventions are used. In this example, the development of educational technology was the primary learning engineering challenge accomplished through the learning engineering process, but how to help instructors teaching in such varied circumstances became an entirely new educational challenge to be solved. The need to support instructors to enact learning technology or educational interventions in a meaningful way within their unique teaching and learning circumstances is a nearly universal challenge. Even with educational technology that conforms to the latest research in the learning sciences, the enactment of that resource in a specific educational setting will strongly inform student engagement and outcomes with that resource. This challenge is one that all creators and developers of educational solutions should consider carefully and attempt to solve using the iterations of the learning engineering process.

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Time-Effective Logistics of Project-Based Course Electronic Instrumentation

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***Abstract*—Historically, the classic course Electronic Instrumentation was based on analog electronics - analog sensors, actuators, and amplifiers - and was taught in most colleges and universities as the theoretical course. The appearance of inexpensive micro-controllers revolutionized the usage of sensors and actuators; hence, our days Electronic Instrumentation can be taught as "a classic course in the modern envelope": by using as analog as digital elements, plus by using special programming techniques. In order to make the content of the course closer to modern industry design techniques, most of the assignments were made project-based. It is clear that checking and grading a large number of project-based assignments is time-consuming. To make this process time-effective for the educator, a set of rules and procedures were formulated. This article describes the time-effective logistics which were used during the 7 years to teach this course, as in "regular time", as in "COVID19 time" by using real electronic components, and by using TinkerCad simulations.**

Keywords-project-based learning; time-effective logistics; electronic instrumentation; TINKERCAD.

I. Introduction

Starting from the 80s, electronic analog systems were gradually replaced by digital systems containing “the wonder chip Micro-processor” [1] [2]. Large control panels equipped with analog voltmeters, ammeters, and mechanical switches were gradually replaced by compact digital systems with visual display units. Programming of the Micro-processors has become an important part of electronic engineering education.

In the past, the classic course Electronic Instrumentation was based on analog electronics - analog sensors, actuators, and amplifiers. Hence, in the majority of universities and colleges, this course was taught as a theoretical course – mostly, due to the high cost of the real-life systems utilized then in the industry. The appearance of inexpensive microcontrollers revolutionized the usage of sensors and actuators, hence our days Electronic Instrumentation can be taught as "a classic course in the modern envelope": by using as analog as digital elements, plus using special programming techniques.

Many educators in the field of electronic instrumentation have emphasized that practical training is an essential part of the learning process. In most of the following steps: "conceive, experiment, design, build, test, improve" – practical aspects are critical for understanding the items learned [3]. Leading educational institutions like MIT [4] and others incorporate into their curricula of electrical engineering a substantial amount of 'hands on' lab skills, by using real electronics components and basic electronic equipment.

Alternatively, a number of educators have experimented with online training technologies. Those attempts have become vital because of COVID19 situation. The current situation in education, which is still seriously dependent on the epidemiological situation, makes educators look for new ways and specific platforms as a means of implementing their educational programs [5]. It was necessary to provide a way to carry out electronic experiments and assignments, as in a real laboratory, as in a student’s home. An interesting option was to use the online TinkerCad platform for implementing at least some elements of the Electronics Laboratory activities [6].

An additional idea was to lease to each pair of students a kit containing real electronic components so that students would be able to execute assignments at their homes – by using the kit and PC. Some elements of this idea were partly described in [7]. This article describes additional details and new elements introduced in the recent years.

Section II describes “Elements of the Course” – such as lectures, exercises, non-obligatory “Class Micro Works”, homeworks and MicroProjects including details: how they were provided in “regular times” and in “COVID19” time. Section III describes implementation details of “Logistics of Homeworks and Micro Projects”. Those details are provided in two sub-sections: sub-section “A” – named “Homeworks: Electronic Projects executed by using real components and by using TinkerCad simulations” and in the sub-section “B” - named “Micro-Projects: description of existing designs and TinkerCad simulations”. Important part of any “time-effective” logistics of that kind is time-effective grading. Details are described in Section IV named “Time-Effective logistics of reports checking and grading policies”. Section “V” shortly summarize results of student’ pools (partly published in the previous publications) and provides some ideas to be weighted for the implementation in the future.

II. Elements of the Course

Course Electronic Instrumentation in the new format was provided at the Department of Electronics of ORT Braude Academic College of engineering every semester starting from 2015. Elements of the course are: 13 two-hour frontal in campus lectures, 13 one-hour in campus exercises, three

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homeworks, two Micro Projects, and 10 non-obligatory “in Class Micro Works” (CMW, - provided during exercise hours). Homeworks and Micro Projects are executed by pair of students at their homes by using specially prepared kits (to be described later). In the process of practical implementation of homework, students compiled reports by using specially designed PowerPoint templates and sent them by Gmail. To make the evaluation and grading of these reports time effective for the educator, special format was developed. The main ideas of this format (albeit for the course “Image Processing”) were described in [8]. After two Micro Projects were executed by pair of students, students sent compiled PowerPoint reports to the lecturer for preliminary evaluation. After corrections, students presented their Micro Projects in class. Micro-exams were individual assignments solved by students on paper. During three semesters starting from March of 2020 to August of 2021, this course was provided under COVID19 restrictions by using online tools: ZOOM, TinkerCad, and Gmail. Specifically: lectures were provided by using remote ZOOM sessions, and assignments were executed by using TinkerCad simulations instead of using real components. Starting from October 2021, the course is provided in a hybrid way: lectures are provided at the campus, but with ZOOM “on”, so that students have a choice: to visit the campus, or listen to the lectures by ZOOM from outside the campus. Homework and Micro Projects are executed by using the kits, but in some situations, students are asked to provide simulations by using TinkerCad and/or MultiSim simulation applications. Grading policies are described at Section IV.

III. LOGISTICS OF HOMEWORKS AND MICRO-PROJECTS

In the subsection “A” logistics of homeworks is described, whereas logistics of Micro-Projects is described in the subsection “B” is described.

A. Homeworks:Electronic Projects executed by using real components and by using TinkerCad simulations

At the beginning of the semester, pairs of students get from the lecturer a specially prepared kit. Specifically, in the frames of the course Electronic Instrumentation, students get: an Arduino UNO R3 board (see item 1 on Figure 1), a small-size breadboard (marked as 2 on Figure 1), a shield with a small breadboard (marked as 3 on Figure 1), a short USB cable, set of wires, and a plastic box (marked as 4, 5 and 6 on Figure 1) and a 37-sensor box (marked as 7).

Electronic modules (sensors and actuators) inside the “37- sensor box" are voltage compatible with the Arduino UNO R3 board. Some modules were extracted from the box – for example, the laser module – in order to prevent possible eye injury in case of reckless usage.

Figure 2 presents simplify flowchart of the steps expected to be executed by educator and by pair of students in the frames of the described logistics. In the frames of homework assignments, students were asked to design, assemble, and test a simple electronic system containing a number of sensors and actuators that are controlled by the Arduino board. Additionally, students were asked to create a program (sketch) for the Arduino board according to the description provided by the educator. It is important to mention, that homework assignments were executed by students at their homes, and thus, the educator could not see how the required design and assembly steps were executed. Hence, students were asked to document the assembly of the system by adding a set of photos to the PowerPoint report. Figure 3 presents exemplary photos taken from the typical student’s report. By exploring those photos, an educator can in a number of seconds validate if students properly put the modules on the breadboard, properly executed interconnections on the breadboard by using colored wires, and properly connected pins of the Arduino board. Additionally, students were asked to fill a number of tables in which they specified all the connections by using special codes and specify colors of wires. It is clear that any discrepancy with the connections specified in the tables and on the photos will be immediately revealed by the educator, hence the requirement to add photos of the assembly steps and the requirement to fill the connections tables is important in the frames of the selected logistics. Yet, additionally, every pair of students were asked to physically demonstrate the operation of their system in the class and answer some questions concerning the report and system operation.

As it was mentioned above, during three semesters starting from March of 2020 to August of 2021, this course was provided under COVID19 restrictions. During those semesters, the distribution of real electronic components became at least problematic, but working in pairs with real components became impossible. The possible solution was to use online TinkerCad simulations. An important feature of this simulation is that it is a free cloud service, so that no installation is needed. However, when COVID19 restrictions were pronounced, it was not immediately apparent that this specific TinkerCad cloud service could be used in the frames of this specific course. Fortunately, in less than 3 days after the pronouncement of COVID19 restrictions it was proved that only minor changes in the requirements for the homework assignments were required. Figure 4 presents screenshots of the TinkerCad screens. The left screenshot demonstrates an exemplary modules layout on the breadboard as it was prepared by the lecturer. This screenshot was given to the students as a slide in order to demonstrate to the students that Homework 01 can be executed by using TinkerCad simulation. During the exercise provided by ZOOM, the lecturer provided a live demonstration of the system operation in full accordance with the description. However, the code of the program (sketch) was not revealed to the students. So, students were asked to do with TinkerCad simulation actually the same steps as with real components: to position modules and to connect them by wires, but, instead of real photos of real components, screenshots of the simulation screens were used. The right part of the Figure 4 presents the layout of the system as prepared by some pair of students. Again, the educator, by exploring the link to the student’s simulation, can very quickly validate that all the blocks were properly connected by color wires. The parts of the student’s report describing the code and testing the system were nearly the same as in the case of real components, so that grading of the

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report by using a specially prepared list of requirements was fast and simple. Additionally, students were asked to demonstrate operation of the system during exercises by using the “share screen” feature of ZOOM. It is clear that if some pair of students had "copied" photos and "code" from the report of another pair of students, this would be immediately revealed. During 7 years, such "illegal copying" was revealed less than 10 times.

B. Micro-Projects: description of existing designs and TinkerCad simulations

In the frames of the course, students were asked to prepare two Micro-Projects. It is clear that students have limited time to implement full-scale projects containing both theoretical part and implementation of some system with real components. Hence, the name used for this assignment is Micro-Project.

The first micro project was about different types of motors (6V DC, Servo, Stepper, and Brushless). Each pair of students prepared a PowerPoint presentation about a specific type of motor, about a specific type of electronic controller and, present it in the class (in the case of “regular” semester) or by ZOOM (in the case of “COVID19” semester). In these presentations, students were asked to explain the physical principles of the specific motor operation and explain how this motor can be controlled electronically by presenting the exemplary circuit needed to control this motor from a microcontroller.

The second Micro Project was about creating an Automatic Measurement System (AMS). Each pair of students was asked to develop a different type of AMS: an AMS for measuring DC voltage in the different voltage ranges, an AMS for measuring AC voltages in the different voltage ranges, etc. Students were asked to prepare the electric circuit of the AMS, provide relevant calculations, and prepare a TinkerCad simulation (including the analog part, Arduino UNO R3 board, and Arduino sketch). In this case, each pair of students was asked to send a PowerPoint presentation and link to the TinkerCad simulation.

IV. TIME-EFFECTIVE LOGISTICS OF REPORTS CHECKING AND GRADING POLICIES

Considering the limited number of kits, and the typical size of electronic laboratory, the number of students in this course was limited to 24, that is, by 12 pairs of students. It is clear, that checking 12*(3+2) reports is a time-consuming job. Hence, significant efforts were made to develop time-effective logistics (a set of formal rules) describing how exactly students must prepare and send their assignments. Our days it is obvious for most educators that reports must be sent electronically (and not collected physically as reports printed on paper). A number of pedagogic systems (like MOODLE) exist for collecting students' assignments. However, most elements of this logistics were developed nearly 15 years before [9]. Then the logistics were based on using Gmail cloud services. During the years, this service was proved as simple and reliable. Hence, there were no serious reasons to change usage of Gmail cloud services as a proper tool to send and store student’ reports and PowerPoint presentations. It is known that some educational institutions strictly forbid using of Gmail and other Google services. In that case, alternative e-mailing or messaging services can be used, while those services have searchable subject field and support attachments, so that using Gmail is not a critical element of the described logistics. A simple, but really time-saving element of this logistics is the naming rule of the assignment materials. The same “name” was used as the Gmail subject, the name of the attached PowerPoint presentation, and the name of the attached zip file (containing code). This name can be described as a set of tokens divided by the delimiter “-“. In the course Electronic Instrumentation this name was:

“ABCD-EFGH-X-YYYY-MM-DD”

ABCD stands for the last four digits of the ID of the first student. EFGH stands for the last four digits of the ID of the second student. The obvious rule needed to prevent ambiguity was that ABCD < EFGH. X – describes a type of assignment – HW01, HW02, and HW03 – for the homeworks 01, 02, and 03, and P1Z and P2Z for the Micro Project 1 and Micro Project 2, where Z is a number of assignment (typically in the range {1..6}, so that every assignment was typically executed and presented by two pairs of students. YYYY is a year, MM is a month, and DD is the day on which the assignment was sent. This naming rule enables a very fast and simple search for the specific report, for all the reports of a specific group, for all the assignments of a specific type, etc. Figure 5 presents exemplary screenshots of the lecturer's Gmail. On the left screenshot of Figure 5, an exemplary result of search for “all assignments of the specific pair of students” by using their short ID token “1576-7618” is shown. Two items emphasized by BOLD exploits a known feature of Gmail: signaling to the educator that this specific mail was not opened yet, and, thus, this specific report was not graded yet. On the right part of Figure 5, an exemplary result of search for “all students that have sent reports for the homework 01” is shown. In this case, search was executed by using token “-HW01-“.

It is important, that when one student sends the assignment to the lecturer, he/she is asked to send a CC to the email of the second student. This simple rule effectively prevents the non-pleasant claim “lost report”. In the case of a problem, students were asked to send a screenshot of the relevant email page as solid proof that the requested report was sent on the specific date. Actually, during 15, years fewer than 5 claims of “lost report” were raised and none of them was found to be valid after simple search together with students.

In order to provide fast, equal, and fare grading, Excel templates were prepared. Figure 6 presents an Excel template for grading homework 01 in the "COVID19 semester". Rows of the template contain an exact copy of the requirements as they are specified in the description of homework 01. Every row has a special code (for example, HW01.11). Students were requested to type this code in the title of the relevant slide of the PowerPoint presentation. This simple numbering makes grading extremely simple and clear both for the educator and for the students. It is important, that requirements to be executed are written in a short but unambiguous fashion. For example, the requirement in the row HW01.13 on the left part of Figure 6 is “Fill Table 3 of the wire’ connections”. It takes some time and efforts for the students to properly fill this table. They cannot use the work of other students because every pair of students uses a different layout of the modules, and then the connections of wires must be different. While executing and documenting this sub-task takes some time for the students, the time that the educator needs to check if this specific requirement was executed as required is very short – less than one minute. In order to make grading even faster, it is recommended to use a PC with two monitors (or a PC with a wide monitor). The first monitor is used to present the Excel grading template. On the second monitor, the educator opens the PowerPoint presentation of the specific pair of students and compares the content of the slide labeled as, say, HW01.11, with the requirement. Then, by using the maximal grade for this item (specified on the next right column), the educator updates the grade for the specific pair of students. In case it is necessary, educator adds comments to the relevant cell, so that students can see why the grade was reduced. Typically, on the rightmost cell of this row, typical students’ errors are listed, and for every “typical error” a simple number is assigned. In that case, it is enough to use this number in the comment - that is: much less for the educator to type. It is important, that this procedure makes grading more fair – “the same grade for the same error”. The final grade of each pair of students for the specific report is automatically summarized in the row marked as “total”. The template presented at Figure 6 contains “non-final” grades. It can be seen that some pairs of students have already sent PowerPoint presentation, but their simulation did not work as expected. In that case, students were asked to demonstrate their simulation and answer the educator’s questions. The grading policy was that for the homework 01 students were permitted to correct their presentation. (Maximum two times). As for homework 02 and 03, only one version of the Report and simulation were permitted.

Figure 7 presents an Excel template for grading Micro Project 1. The basic structure of this template is the same. While homeworks were the same for all pairs of students, Micro Projects were different for different pairs of students. Considering that in this specific semester six different types of motors were used, typically two pair of students had the same assignment. Again, significant efforts were made to formulate the requirements in a short but unambiguous fashion. For example, row “P1V.13” (V stands for the project number) clearly states that photos of two commercially available motors must contain explanations of the pins of those motors. Again, the grading policy in this assignment was to enable three versions of the PowerPoint presentation. It is clear, that in that case most of the student’s pairs arrived to the maximal grade. The goal of this “trick” was that to force students to understand the level of requirements of the nearly industrial-grade report. Obviously, only one version of the Micro Project 2 presentation was permitted. The final grade was calculated by Excel according to the self-explanatory formula: A=0.05*HW1+0.1*HW2+015*HW3+0.3*MP1+0.4*MP2;

Final Grade = G = MAX (0.2*CMW + 0.8*A , A) ;

Where CMW stands for the grade of non-obligatory “Class Micro Works”. ”.

V. CONCLUSIONS AND FUTURE WORK

During 10 years, different variants of this time-effective logistics for the different electronic engineering courses were tested. Some results were published before in [7] [8] [9] and reported at a number of international conferences. In the semesters when student’ pools were provided, grades provided by students for this course were in the range {4.23...4.94} (by using 1-5 scale) and was in most cases by 0.5 higher that mean department’ courses grade. In the written comments, most of the students’ remarks were positive, and, median grade for this course in most of the semesters was 5.0.

Currently, management and processing of all the Emails are executed manually, mainly by exploiting email search utilities. Manual management and grading of the student's reports (by using grading templates) was found simple and time-effective, as for the students, as for the educators. While the course is provided for a group of students of limited size (say, up to 24 students), automatization of the above management by creating dedicated software scripts or by creating special software, does not look as important improvement of the logistics. However, for the large groups, such automation may be found instrumental.

An additional automation option is to include elements of the discussed logistics as an additional module to any available ELM. Specifically, in the ORT Braude Academic College of Engineering, a number of ELM were tested. Currently, MOODLE system is used by most of the college lectures. However, in its current implementation, using MOODLE was found as less suited for the goals of this specific course than the proposed Gmail-based logistics.

It is assumed, that by analyzing the results of the last student pools, more conclusions will be drawn, and some modifications in the logistics will be provided.

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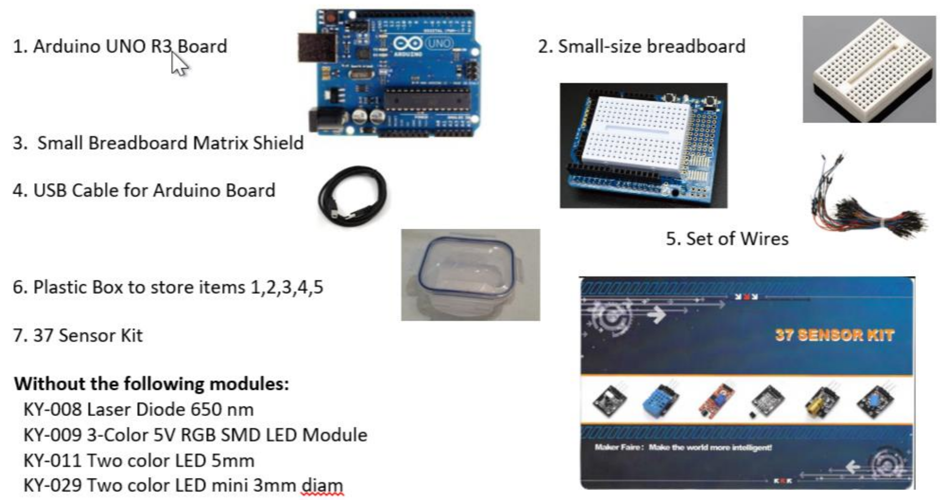

Figure 1. A list of electronic components that were provided to the students for the work at their homes.

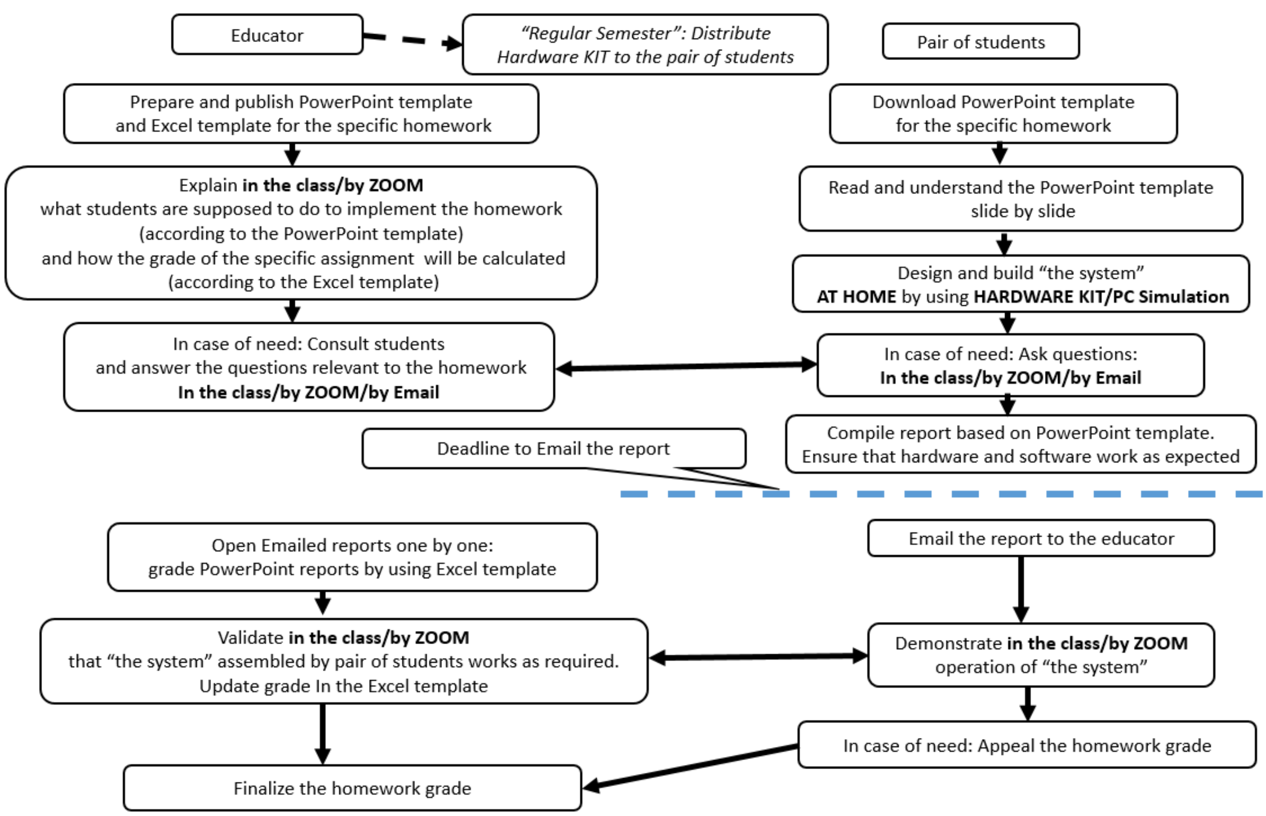

Figure 2. Simplified flowchart of the exemplary homework roadmap.
Left: actions of the educator. Right: actions of pair of students

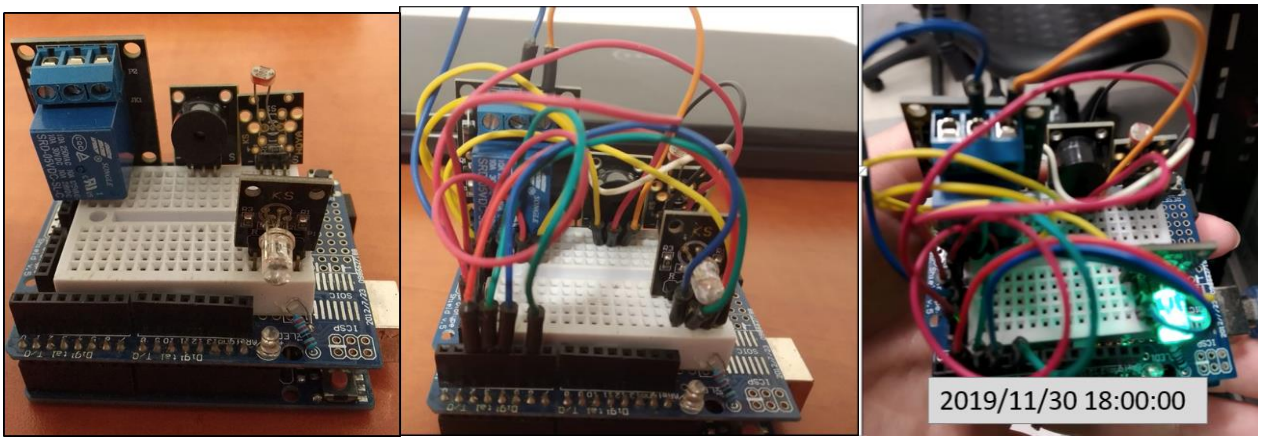

Figure 3. Homework 01 as impmenented by pair of students by using real electronic components.: Left: A photo of the system with four modules positioned on the breadboard. Center: a photo of the system with colored wires added. Right: photo as proof that the system works as required.

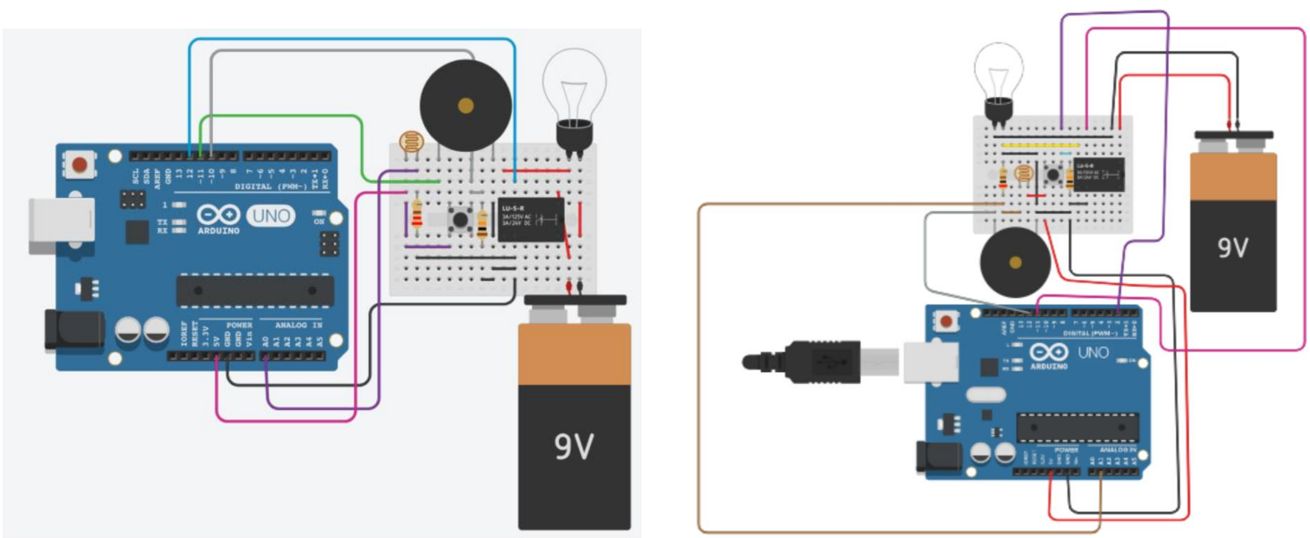

Figure 4. Homework 01 impmenented as a TinkerCad simulation .Left: Exemplary layout of components as proposed by lecturer. Right: layout of components as created by pair of students

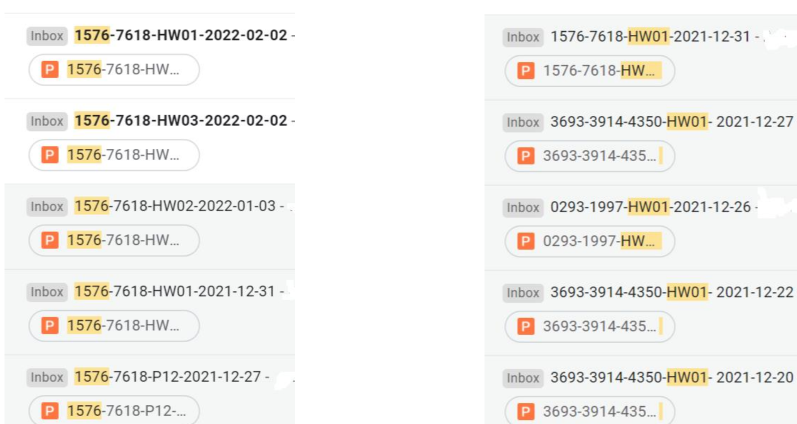

Figure 5. Screenshots of the lecturer's Gmail. Left: Results of search for all assignments of the pair of students by using the short ID token "1576-7618". Marked as Bold : works that have not been checked and graded yet. Right: Search of all reports of the homework 01 by using token "-HW01-"

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	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Num	Item	Max Points	4216-4960	2553-5282-8676	0293-1997	3509-4152	3693-3914-4350	3447-4989	0437-6198	1576-7618	1624-1671-8387	3693-3914-4350	5424-6813
5		Kit Number		11	12	13	14	15	16	17	20	18	?	19
6														
7	HW01.11	Put here at least **SIX** clear screenshots of the modules positioned ONE by ONE on the breadboard WITHOUT WIRES. Put here **FIVE** clear screenshots of the modules positioned on the breadboard: With all wires connecting different holes of the breadboard With all additional wires connecting sensors and/or actuators going to Arduino IO Pins With all additional wires going to the Ground With all additional wires connected to the 5V With all additional wires connected to the 9V battery and to the Light Bulb Lecturer must be able to "reverse engineer" your shield in case of need	1	1	1	1	1	1	1	1	1	1	1	1
8	HW01.12	Fill table of of the Component' position on the mini breadboard For Components use Format: X.Y (X – Number of the component in the Table 1 Y – relevant alpha-numerical descriptor of the pin – invent your STANDARD in case of need) For the mini-breadboard use hole-descriptors like A1-D2	1	1	1	1	1	1	1	1	1	1	1	1
9	HW01.13	Fill Table 3 of the wire' connections	1	1	1	1	1	1	1	1	1	1	1	1
10	HW01.14	System' Electrical Circuit must contain all components and all the connections Pins of all the components must be clearly marked	1	1	1	1	0	1	1	1	0	1	0	1
11	HW01.15	Block-Chart of the System' operation	1	1	1	0	0	0	1	1	0	1	0	1
12	HW01.16	Test Report of System' operation 0 is OK	-5	0	0	0	0	0	0	0	0	0	0	0
13		Simulation 0 is OK	-5	0	0	0	-5	-5	0	0	-5	0	0	0
14		Total:	-5	5	5	4	-2	-1	5	5	-2	5	3	5

Figure 6. Excel template for grading homework 01.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Num	Item	Max Points	4216-4960	2553-5282-8676	0293-1997	~~3509~~-4152	3693-3914-4350	3447-4989	0437-6198	1576-7618	1624-1671-8387	5424-6813
2		Project Num (V)		1	2	3	4	5	6	1	2	3	5
3		First Version Date		12-02	12-02	12-02	NONE	12-02	12-02	11-30	12-02	12-02	12-02
4		Second Version Date		12-21	12-20		12-20	12-02	12-16	12-20	12-13	12-16	12-05
5		Final Version Date			0102		12-27	12-26	12-26		12-27	12-28	
6		Presentation Date and Time		12-21	12-21	12-21	NONE	12-21	12-21	12-21	12-21	12-28	12-28
7									01-08				
8	P1V.11	Mechanical and Electrical Elements of the motor (drawings and explanations)	3	3	3	3	3	3	3	3	3	3	3
9	P1V.12	Physical principle of the motor operation (drawings and explanations)	3	3	3	3	3	3	3	3	3	3	3
10	P1V.13	Photos (from Internet) of at least TWO commercially available motors with pins explanations	2	2	2	2	2	2	2	2	2	2	2
11	P1V.14	Important parameters of above two motors (names and typical values and graphs with VALUES) + explanations & comparisons;	4	4	4	4	4	4	4	4	4	4	4
12	P1V.21	Full Electrical circuit of a motor controller (in case of IC – what exactly is inside IC)	4	4	4	4	4	4	2	4	4	4	4
13	P1V.22	Photos (from Internet) of at least TWO commercially available motors controllers with pins explanations	2	2	2	2	1	2	2	2	2	2	2
14	P1V.23	Full electric circuit containing Arduino, Controller, Motor, External Power supply (if relevant)	4	4	4	4	4	4	2	4	4	4	4
15	P1V.24	Explanation: how speed and direction of a rotation can be changed by Arduino Commands	4	4	4	4	4	4	3	4	4	4	4
16	P1V.25	Evaluation of speed (RPM) limits. Explanation of a typical torque behavior	2	2	2	2	2	2	2	2	2	2	2
17	P1V.3	Numbered list of sources (IEEE Style)	2	2	2	2	1	2	2	2	2	2	2
18		Presented (-5)	0	0	0	0	-5	0	0	0	0	0	0
19		Total	30	30	30	30	23	30	30	30	30	30	30

Figure 7. Excel template for grading Micro Project 1.

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Using the Tools at Hand: Creative Online Course Quality Management

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***Abstract*— Post-pandemic, a requirement that online courses be certified for accessibility and meet federal guidelines for instructional equivalency created a backlog of courses that needed to be processed quickly and efficiently. This situation was particularly acute in the Norman J. Radow College of Humanities and Social Sciences, the largest College at Kennesaw State University, and its 11 component schools and departments. Without the availability of increased staff or funding, efficient workflow management systems needed to be established quickly and using software already available at the institution. Team members developed the "Bucket System" based on multiple components of Microsoft 365 to map and track workflows across multiple criteria and multiple reviewers.**

Keywords-course review; online course quality; project management; Microsoft 365.

I. Introduction

In 2018, Kennesaw State University (KSU) President Pamela Whitten chose to discontinue the requirement of Quality Matters (QM) Certification for all online classes. Colleges within the university could still require quality control, but it was left to college leadership to decide if and how to implement this control. The Radow College of Humanities and Social Sciences (RCHSS) continued to offer training and certification options for those departments requesting support. Training and certification were also built into compensation contracts offered by the college. Despite these continued options, the college decided to allow the requirement for instructor and course certification to lapse.

Instead of following QM, which cost money and received opposition from faculty resistant to the latest version update, digital education experts in what was then the Distance Learning Center partnered with faculty to develop a set of standards that fit the university's needs and aligned with best practices. This process ultimately resulted in the KSU Course Quality Checklist (KSU CQC) and was approved through various shared governance bodies. While some colleges chose to remain with QM (after memberships were provided through the University System) and others developed their own rubrics, the KSU CQC was adopted across multiple colleges at the university and has become the standard quality measure in RCHSS in instances when course review is required.

When the pandemic hit in March 2020, the focus across KSU shifted from offering high quality courses to simply *offering* courses. Suddenly, everyone needed to be online. Professional development shifted with the needs of faculty and training facilitators as they struggled alike to adapt to the relatively new modality of synchronous online education. The nearly four-month period of online-only education at the start of the pandemic allowed misconceptions about online teaching and learning to spread as digital learning experts scrambled to teach basics to faculty with little-to-no online experience. Then, in Fall 2020, as the return to campus began, faculty were expected to teach in various rotational and hybrid formats with many having had little-to-no training in these new modalities. This trend continued into Spring 2021, with a complete return to campus planned for Fall 2021. By this point, the combined effects of eliminating required instructor and course certification for online offerings and unsound pedagogical approaches created by pandemic pandemonium were beginning to manifest in student complaints about the quality of online education.

The authors first present a description of the context and magnitude of the challenge to be addressed. The paper then details the project management system developed to facilitate the workflow of the overall process and the ancillaries intended to help faculty master the skills necessary to have all courses certified by the university's deadlines.

II. The Problem

After a change in leadership in July 2021, KSU's Office of the President charged the Division of Curriculum and Academic Innovation (CAI) with ensuring that all digital course content met recently updated federal guidelines and the University System of Georgia Board of Regents policy on accessibility standards and sustained instructor interaction. Each college, in turn, was asked to submit a review procedure for all online and hybrid courses. While many colleges already possessed the requested review procedure, the lack of required review since 2018 meant RCHSS was faced with creating and implementing a new review process in a limited window of time.

A. The RCHSS Proposal

The RCHSS Office of Digital Education (ODE) solicited input from faculty and college administrators and created three plans for reviewing asynchronous online, synchronous or hybrid online, and *template* courses (defined as courses created in entirety by faculty designers but taught by other course facilitators). These processes were then vetted through the appropriate college faculty governance channels. The CAI charged each college with developing and implementing their plans by the start of Spring 2022, which gave the ODE team roughly five and a half months to solicit feedback, adapt the KSU CQC for hybrid and template courses, update faculty certification trainings, and develop all tools (including communication and project management tools) needed to implement the initial two-year review cycle.

No new resources were provided at the university or college level to support this initiative.

B. *A Larger College, a Larger Problem*

The five-month implementation timeline and two-year review timeline were reasonable for most other colleges at KSU. However, RCHSS is, by far, the largest college on campus, with 425 faculty and 8,500 students enrolled in majors within the College. RCHSS is responsible for eight of the fourteen general education standards required for institutional accreditation. As shown in Figure 1, of those eight standards, the college offers 50 different courses that can be completed to fulfill the requirements, compared to 22 courses offered by a mix of the Coles College of Business, the College of Science and Mathematics (CSM), and the College of the Arts (COTA) across the remaining six standards. In Fall 2021, RCHSS offered 35% of undergraduate course sections and 41% of graduate course sections, totaling 750 sections, in the online modality (Figure 1).

Of the eleven departments and schools in RCHSS, two have completely rejected the idea of template courses outside of use for emergency hires and two regularly use template courses. The remaining seven departments reserve template courses for adjunct or emergency use only. This practice is in contrast to other colleges at the university. For the most part, other colleges only utilize template courses or are so limited in size as to require one or two course builds to meet class section needs. Because the Radow College is focused on disciplines in the humanities and social sciences, RCHSS has dozens of sections of one course, all with unique designs, to allow faculty to teach to their strengths and provide their expertise to students. For example, many faculty teach American literature online, and yet each professor has a different specialization. When each faculty member creates his/her/their online course according to best practices and capitalizes on his/her/their area of expertise, students get the best instruction and experience. Additionally, bespoke course designs allow for continued variety in perspective and approach, avoiding some of the pitfalls of intellectual and cultural homogenization.

The ODE team had little time to prepare for this project and had no formal structures or tools in place to accommodate a project this large. The structures and tools previously used needed to be adapted to accommodate a higher volume of course designs reviewed in a shorter amount of time. This article outlines the RCHSS course review process, how the team implemented it, where we are, and where we are headed.

III. Project Management Tool: The "Bucket System"

It takes an average of three to five hours to review each course, contingent on the course content and approach. Based upon pre-pandemic numbers, the team had anticipated reviewing a total of approximately 750 courses over a two-year period. In spring 2022, we expected 135 courses to be submitted for review. To date, 192 courses have been submitted. Projected forward, we are now anticipating reviewing around 1000 courses over the next two years using a team of two instructional designers, three faculty, and four student assistants.

The most comparable project undertaken by the team was a review of 115 partial courses across a seven-month period, which was tracked in an Excel spreadsheet. At the time, our team consisted of one instructional designer, two faculty, and two senior student assistants, and all were able to assist in the review process.

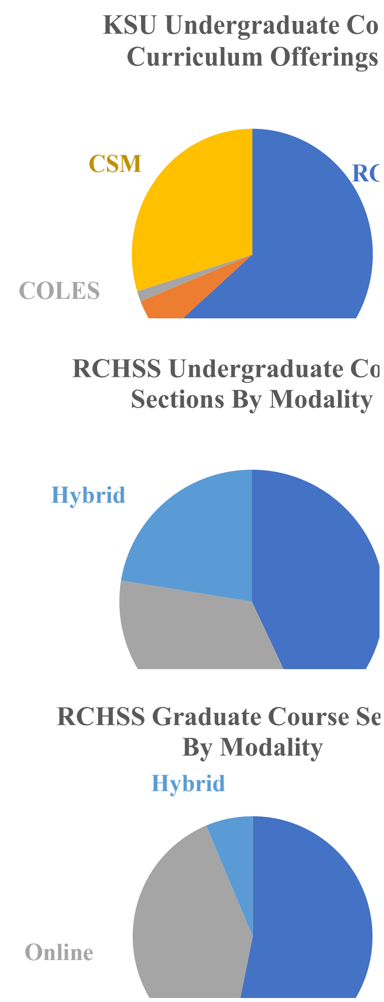

Figure 1. Three charts showing the division of courses across KSU and within the college.

For the much larger challenge now faced, we developed what we have christened as "Bucket System." Our system was devised as an easy way to physically move items along in a workflow and provide more flexibility than an Excel spreadsheet. After reading and watching project management tool reviews and testimonies from other higher education teams [1][2], the team met and compiled a list of the features we would need.

- Access for at least 10 people
- Reporting functions and the ability to connect files to the task
- Ability to assign tasks
- Ability to create subtasks
- A visual marker for where the course was in the review workflow.

Our team also decided that we preferred a more visual interface, as opposed to a simple task list. Most importantly, all of this needed to be located in a no-cost or extremely low-cost tool.

Tools like Slack [3], Trello [4], and ClickUp [5] had been utilized by the team before but required monthly subscriptions for large projects. Open-source tools like OpenProject [6], and Focalboard [7] all had the key features the ODE team needed but also had annual hosting costs, usually upwards of $150USD. Products offered by ServiceNow [8], BMC [9], and IBM [10] were much more robust than needed for this one project, so they were not considered.

The team devised a plan to build something similar to these systems utilizing various Microsoft applications, as the University had recently moved to Microsoft 365 [11]. This project management tool would be modeled after existing tools [12] but would be customized to our specific needs. Microsoft Planner had the tools we would need at a task-management level (file connection, task assignment, reporting functions, and subtasks) and had several layout options. It was also integrated with Microsoft Teams—which would create a localized "dashboard"—and Power Automate, Microsoft's backend automation and workflow application, which would be crucial in populating the system. Microsoft Lists had similar functions—and the bonus of custom metadata fields—but lacked the visual layout we wanted. Ultimately, the goal was to produce a Kanban-like system of workflow visualizations, but we did not have the luxury of limiting work in progress (WIP), required in a true Kanban system [13].

We had three factors to consider when developing our workflow [14]. First, we needed to abide by the processes put forth by the departments in our college. Because our college is so large, the RCHSS Digital Education Council requested that each department be allowed to submit their own process to us. The outcomes from this request were varied: seven departments decided to defer to the ODE and have us carry out all reviews; one department decided to do the same but added additional faculty support by way of a mentoring committee; and three departments decided to conduct all parts of the review, with minimal support from the ODE.

Second, our undergraduate student assistants are only able to conduct the accessibility portion of the review, not to make decisions concerning content and pedagogy. One section of the KSU CQC is dedicated to digital accessibility. The review process for this section is very clinical, so it can be completed by students without years of instructional design experience.

Third, the sheer number of courses was overwhelming to a team with only five people qualified to evaluate entire courses. Department schedulers indicated a slow return to pre-pandemic scheduling practices, so we estimated that we would need to review 135 courses across the Spring 2022 semester. We decided to translate this process into Microsoft Planner. Planner utilizes columns called "buckets" and projects called "cards" (Figure 2). Each bucket represents a step in the workflow, and each card within a bucket represents an individual course. Thus, the "Bucket System" was born.

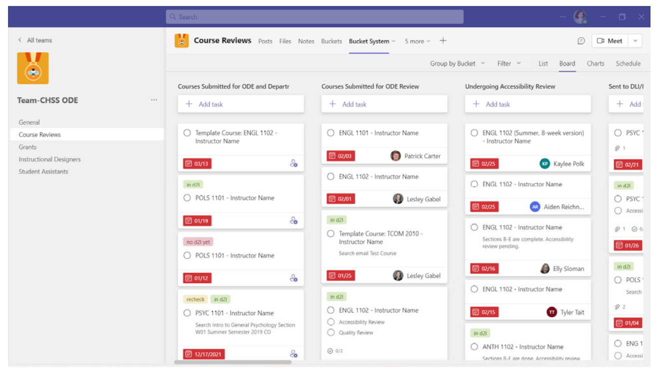

Figure 2. Screenshot of the "Bucket System" dashboard.

Within the cards, we initially utilized the tag feature to indicate whether ODE directors had access to the course in the LMS (and, thus, had the ability to add reviewers) and whether the course was undergoing a "recheck" or re-review. We ultimately added a tag to mark course reviews as finished because we initially lost courses that had been dismissed as "complete" (Figures 3 and 4).

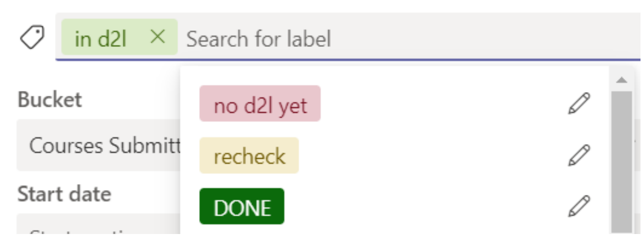

Figure 3. A screenshot of the tagging system the ODE utilizes within the bucket system.

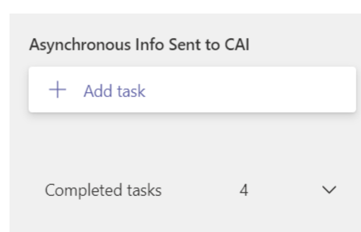

Figure 4. Screenshot showing how tasks become invisible once marked "complete."

We also use the comment section to create a documentation trail regarding when communication had been sent to faculty. The team found that using the "start

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date" feature did little to help prioritize courses, as Planner does not offer a "start date" option under the sorting tool. We instead pivoted to using the "due date" feature, which had the bonus of posting the date on the card. This all creates an easily accessible history of what courses have been reviewed, where they are in the process, and who has completed what (Figure 5).

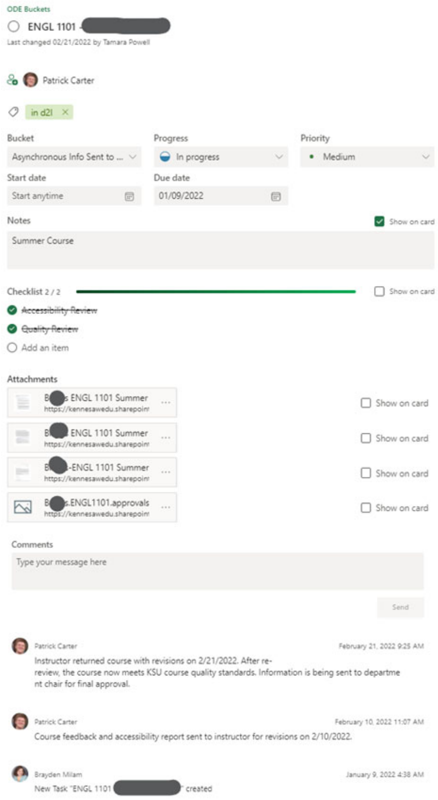

Figure 5. A course review card showing the light green "in D2L tag," a completed checklist, attached documents, and comment trail.

After building the process in planner, the decision was made to integrate the structure with Microsoft Forms, which would allow faculty to submit "review requests." We reviewed the Certified Course Build SmartSheet developed by the CAI, which was designed to track courses certified according to quality standards and included key questions on our Form (Figure 6). Originally, we created one Form for all of RCHSS. As we tested the process, we discovered we needed individual Forms for all eleven departments and schools. This decision was made to minimize confusion, as we initially offered too many review-customization options on a single form, and to streamline the automation process. The automation process is as follows: a faculty member fills out a form, Power Automate pulls information from the Form to generate a Planner card in the correct bucket and then sends a personalized confirmation email to the faculty member (Figure 7).

A key component of this process is faculty involvement. To initiate a review, faculty must submit their courses for review, request new course shells for each course review needed, and add the ODE directors to the new course shells. We wanted to streamline the process as much as possible to make it as simple as possible for faculty, so as not to induce confusion or increase their workloads. The simple form and automated email accomplished most of these goals. We kept the forms as simple as possible, included tutorials on how to request, copy, and add the ODE directors to the course shells in D2L, our learning management system; eliminated an additional step of communication by requesting faculty utilize the enrollment notification option in D2L; and added a layer of familiarity with personalization tools [15]. Ultimately, we have received positive feedback from faculty about how easy the process is.

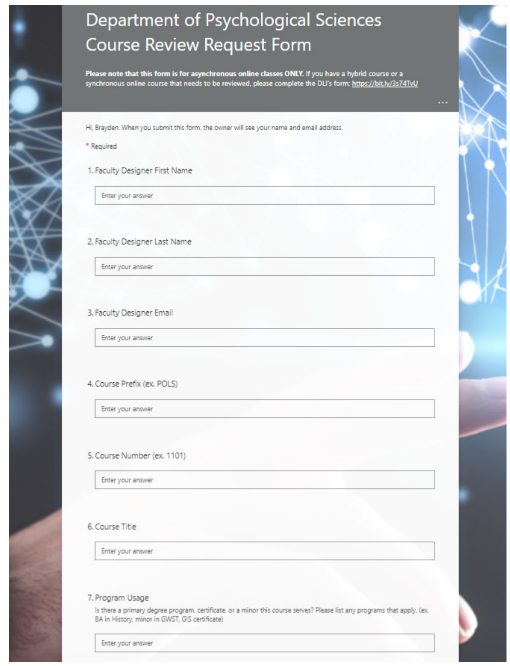

Figure 6. The first page of the Review Request Form for the Department of Psychological Science.

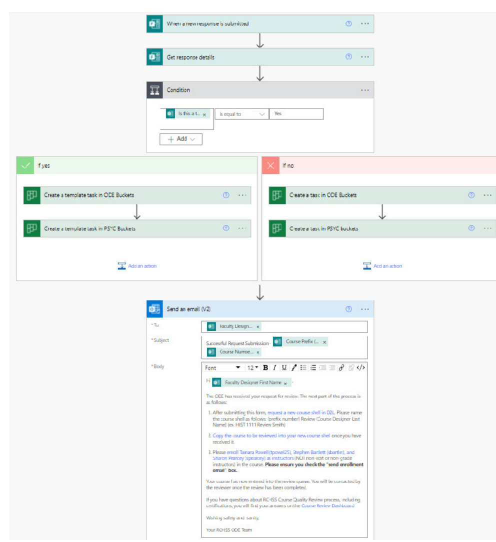

Figure 7. The automated process behind the Psychological Science Request Form, built with Power Automate.

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After the faculty member has added the ODE directors to their course shell, the formal review process begins. At the beginning of each week, the ODE Associate Director assigns courses to ODE reviewers (instructional designers and faculty) and student assistants depending on the courses available for review. Instructional designers and faculty prioritize courses taught by departments with their own review process, while student assistants complete accessibility reviews for courses that are reviewed by the ODE in full. The instructional designers and faculty then complete sections A and B of the review for the courses assigned to them, which require greater familiarity with digital accessibility standards and state and federal mandates, respectively. They then pass the course along to the department liaison/representative so the department can finish the rest of the review. Alternately, students complete section A of the review, which only requires familiarity with standards of digital accessibility, for the courses assigned to them. After the accessibility review has been completed, students pass their reviews on to the ODE instructional designers and faculty, who complete the rest of the review.

Following the completion of the initial review, the review documents are sent to the faculty designer. The faculty designer then works to make the appropriate changes and consults with ODE team members (or their department liaisons) if they need assistance. After the appropriate changes have been made, the course undergoes a secondary review. If the course passes this review, the review documents will then be sent to the department chair for approval. If the course does not pass the review, the revision process begins again. This revision process may be completed up to two times before the course is removed from the queue. If it is removed from the queue, the chair must request reactivation and the faculty designer must resubmit the course to be reviewed without priority.

Once a course is approved by the chair, the ODE Director submits the course to the CAI's Certified Course Design SmartSheet and notifies the program coordinator, who updates the public-facing spreadsheet maintained by the ODE. As of Spring 2022, this process is set to repeat on a five-year cycle. The initial review cycle is based on course level, so all existing courses will have completed the review process by December 2023 and been scheduled for their next re-review.

IV. FACULTY RESOURCES: THE COURSE REVIEW DASHBOARD AND SYLLABUS TEMPLATES

The ODE decided to anticipate the needs of faculty and create resources to aid them in the course review process. The primary resource was the "Course Review Dashboard," which functions as a one-stop-shop for all things related to course reviews, including tutorials, policies and checklist criteria, review request forms, and contacts. This project was designed to be far-reaching and creative. We knew the website needed to be easy to navigate and user friendly, but we also knew how expansive the topics and resources needed to be. We ultimately built eight pages hosted on the site and built an additional site specifically for course reviewers within the departments. We also completely redesigned our tutorial library, which hosted 115 simple technology and software tutorials, for a cleaner interface with a more visual navigation structure (Figure 8).

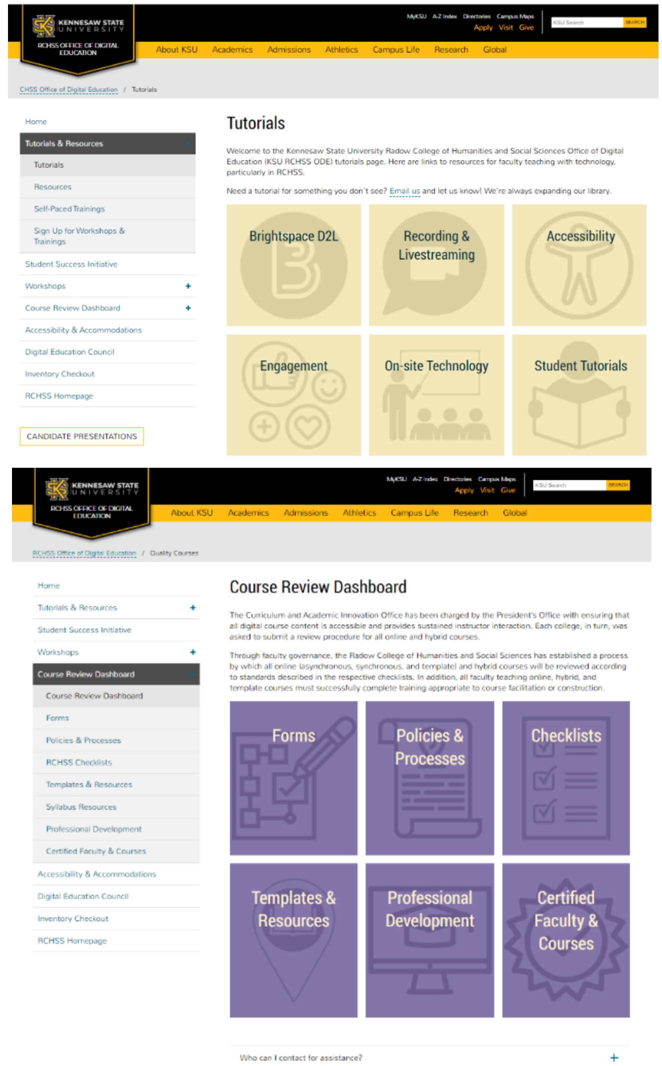

Figure 8. Two screenshots showing the Tutorial and Course Review Dashboard websites.

With a great deal of the accessibility and quality-checklist requirements focused on course syllabi, a significant need for an accessible syllabus template arose. The need to include an ever-increasing number of policies and links to student success tools had placed syllabi templates at the forefront of academic concerns of the university for well over a decade. The updated federal guidelines and University System of Georgia Board of Regents policy only increased the urgency in addressing this need. The greatest difficulty was in "locking" the template so that required items could not be altered or deleted while keeping the remainder of the document open for editing by the instructor. An early attempt at an electronic solution to the syllabus template issue ended in a costly failed attempt to

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partner with a professional technical company. Further attempts at a lockable form were abandoned.

After consulting with the RCHSS Digital Education Council, the ODE found that the new emphasis on accessibility requirements made syllabi templates more desired by faculty. Again, lockability remained the greatest difficulty, as faculty would frequently mistakenly render ADA compliant syllabi inaccessible by altering certain document features. After many hours of research, the team was able to use Microsoft Word to develop a "lockable" template that met accreditation and accessibility standards but remained customizable enough for broad use. The team also worked with the First-Year Composition (FYC) program to develop two syllabi specifically for use in ENGL 1101: Composition I and ENGL 1102: Composition II, two courses all students are required to complete prior to graduation. These templates were created with a variety of Developer Tools, including content controls and "lockable" groups, and general accessibility tools, like Styles and list/table structures.

V. Conclusion

With varying requirements across the eleven schools and colleges that comprise the Radow College, the unexpectedly high number of course submissions, and the need to validate review practices and feedback information across reviewers, much fine-tuning of the Bucket System is still in progress. The overall system, however, is proving to be robust and flexible while providing consistent tracking and information capture.

Because the Bucket System is built on components of Microsoft 365 and accessed through familiar interfaces, the time required to learn to use the system effectively is far shorter than would be the case using other software tools to manage the same project. Bringing new reviewers or content specialists online is also simplified, with no need to obtain additional software licenses or install additional software. It also bridges seamlessly across units within the College and across the University as needed.

The Bucket System has been adapted across multiple course review efforts. Each department with their own review process has a system customized to their needs, including one built for the university-level equivalent of ODE. For example, the faculty member designated as the Hybrid Specialist in ODE is piloting an adaptation of the Bucket System to track and manage a grant-funded Open Educational Resource (OER) project. Collection of user feedback and its application to further refine the software is expected in the coming academic year.

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