Integrating Engagement Inducing Interventions into Traditional, Virtual and Embedded Learning Environments

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Abstract. The key to an effective learning environment is keeping the learner attentive and engaged [51]. The shift towards virtual learning environments, such as online and computer-based learning environments, distance the learner from the instructor and can lead to some less-than-engaging learning experiences. Such environments often lack key attributes necessary to fully engage learners, such as clear goals, adequate feedback, and instructor support. Decades of study in cognitive and educational psychology provide a foundation of knowledge regarding the factors that influence learner engagement, and how we can leverage this knowledge base to create engaging learning experiences in these new technology-driven learning environments. This paper presents a taxonomy that maps ten engagement-inducing learning interventions to learning environments in which they have been found to improve learner engagement, factors that influence learner engagement, and learning gains. Implementation of this taxonomy is then illustrated by presenting a use case implementation within a virtual learning environment, followed by a discussion of important considerations during implementation.

Keywords: Classroom · Online learning · Blended learning · Flow · Involvement

1 Introduction

The key to an effective learning environment is keeping the learner attentive and engaged [51]. Unfortunately, many learning environments, especially those in the military and professional development/training world depend heavily on PowerPoint-based classroom lectures and Computer-Based Training (CBT) environments, which can often be boring and result in disengagement. This is especially challenging for learning domains such as Unmanned Aircraft Systems (UAS) and aircraft maintenance training which may require a great deal of declarative and procedural knowledge absorption prior to actual hands-on training. There is a need to develop training methods and tools to support engagement optimization to increase learning effectiveness and efficiency in these learning environments. The shift towards virtual learning environments, such as online and computer-based learning environments, distance the

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learner from the instructor and can lead to some less-than-engaging learning experiences. Such environments often lack key attributes necessary to fully engage learners, such as clear goals, adequate feedback, and instructor support. Decades of study in cognitive and educational psychology provide a foundation of knowledge regarding the factors that influence learner engagement, and how we can leverage this knowledge base to create engaging learning experiences in these new technology-driven learning environments.

This paper presents a taxonomy that maps ten engagement-inducing learning interventions to learning environments in which they have been found to improve learner engagement, factors that influence learner engagement, and learning gains. Implementation of this taxonomy is then illustrated by presenting a use case implementation within a virtual learning environment, followed by a discussion of important considerations during implementation across various learning environments.

1.1 Influencing Learner Engagement

This paper builds on previous work in which we developed an Applied Model of Learner Engagement, identifying factors that influence the likelihood of a learner to become engaged in a learning context [16]. The model presents influencing factors related to (1) the individual learner (cognitive ability, personality traits, motivation, interest, self efficacy, and anxiety), (2) the learning task (clarity of goals, feedback, level of challenge, enjoyment, and meaningfulness), and (3) the learning environment (level of autonomy, safety and support). These influencing factors provide opportunities for an instructor to intervene to improve learning (See Carroll et. al. [16], for full description of the model and factors).

Utilizing this model as a foundation, we conducted a literature review identifying instructional interventions to be used in the modern educational environment to effectively target these factors, promote engagement, and improve learning outcomes. For the purposes of this effort, we define an instructional intervention as an instructional tool(s) or method(s) that facilitates the presentation of relevant information to be learned, creates opportunities for trainees to practice skills, and/or provides feedback to trainees during and after practice [58]. The criteria for an intervention to be included required empirical evidence indicating that the intervention resulted in: (1) an increase in engagement, or (2) a positive effect on the factors that influence engagement, and (3) learning gains such as knowledge, achievement or performance gains. Ten interventions were identified for inclusion, including: (1) Metacognitive Intervention, (2) Challenge Level Optimization, (3) Goal Clarity, (4) Feedback, (5) Autonomous Self-Regulated Learning, (6) Personalization, (7) Experiential Learning, (8) Game-based Learning, (9) Interactivity and Multimedia, and (10) Meaningful Learning. These interventions are presented in Table 1 along with brief descriptions and example implementations.

Table 1. Engagement inducing interventions

	Description	Example implementation
Metacognitive intervention	Prompt to increase frequency/accuracy of self assessment of [metacognitive] knowledge/ learning process [61]	Prompting students to reflect on the strategy used to solve a math problem
Challenge level/skill optimization	Optimizing challenge to an individual learner's skill level where the difficulty of the learning experience provides adequate challenge without frustration [24]	Increase/decrease difficulty based on performance
Goal clarity	Learning goals presented to learners, and taken up and transparent throughout the learning activity [62]	Provide overviews, transition statements, and summaries
Feedback	Information provided to learner that "aims to reduce the gap between current and desired learning outcome" [70]	Providing areas of performance improvement on a grading rubric
Autonomous self-regulated learning	Strategies that allow learners be engaged in learning outcomes of their own goals; involves "autonomous motivation"; "acting with a sense of volition and choice" [53]	Increase simulator availability so the learners can repeat and master the task and practice at their own pace
Personalization	Tailor instructional content to "student knowledge, interests, preferences, and goals" [13]	Surveying students on interests/goals, tailoring topics/learning content
Experiential learning	Learning from experience; learning by doing. Immerses learner in an experience, encourages reflection about the experience to develop new skills/ways of thinking [44]	Providing a problem scenario and allowing students to work through and find solutions to the problem
Game-based learning	"A system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome" [59]	Adding incentives for completing a math times table within an allotted time
Interactivity & multimedia	Dynamically communicating with an individual by either providing response information or allowing individual to participate through feedback, adaptation, control, or multimedia [64]	Using clickers in a science class; respond to user inputs and display user responses/performance scores
Meaningful learning	Connecting new ideas and knowledge to existing cognitive structures to give new information meaningful connections and to enhance memory retention [8]	Developing a concept map of species to help understand distinction between mammals and non-mammals

2 Taxonomy of Interventions and Learning Environments

A taxonomy was then created that mapped these instructional interventions to the learning environments in which they had been effective. Specifically, the taxonomy identified whether each intervention had been shown to (a) increase learner engagement or positively impact engagements factors and (b) improve learning gains, across one of three learning environments including (1) traditional (i.e., classroom-based), (2) virtual (e.g., computer/simulation-based), or (3) embedded learning environments (e.g., live, on-the-job). An overview of the taxonomy is presented in Table 2 and described in detail in the following sections.

Table 2. Taxonomy of instructional interventions and learning environments

	Traditional	Virtual	Embedded
Metacognitive intervention			
Engagement[a]	✓*	✓	✓*
Knowledge[b]	✓	✓	✓
Skill/Performance[c]	✓	✓	✓
Challenge level optimization			
Engagement[a]	•	✓*	•
Knowledge[b]	•	✓	•
Skill/Performance[c]	•	✓	•
Goal clarity			
Engagement[a]	✓*	•	•
Knowledge[b]	•	✓	✓
Skill/Performance[c]	•	✓	•
Feedback			
Engagement[a]	✓*	✓	•
Knowledge[b]	•	✓	•
Skill/Performance[c]	✓	✓	•
Autonomous self-regulated learning			
Engagement[a]	✓*	✓*	•
Knowledge[b]	•	✓	•
Skill/Performance[c]	✓	•	✓
Personalization			
Engagement[a]	✓	✓*	•
Knowledge[b]	✓	•	•
Skill/Performance[c]	✓	•	•
Experiential learning			
Engagement[a]	✓	✓	•
Knowledge[b]	✓	•	•
Skill/Performance[c]	•	•	•

(*continued*)

Table 2. (*continued*)

	Traditional	Virtual	Embedded
Game-based learning			
Engagement[a]	✓	✓*	•
Knowledge[b]	✓	✓	•
Skill/Performance[c]	✓	✓*	•
Interactivity and multimedia			
Engagement[a]	✓*	✓*	✓
Knowledge[b]	✓	✓	•
Skill/Performance[c]	✓	✓	•
Meaningful learning			
Engagement[a]	✓	•	•
Knowledge[b]	✓	•	•
Skill/Performance[c]	•	•	•

[a]Engagement includes: flow, engagement and task strategies as well as factors: motivation, self-efficacy, value, competence, satisfaction, and interest. [b]Knowledge includes: understanding/comprehension, performance, procedural knowledge, declarative knowledge, transfer of knowledge, perceived or actual learning, retention, and recall. [c]Skill/Performance include: academic achievement, general performance, strategies, training performance, training efficiency, mastery, effort, and information search. ✓ = Show to be beneficial to a trait in this category. • = No research presented on the impact in this category. * = Contingencies for the intervention effectiveness or a mix of beneficial and negative impacts exists.

2.1 Metacognitive Interventions

Metacognitive interventions have demonstrated improved knowledge transfer, higher performance and self-efficacy, increased comprehension and mastery, and more efficient use of learning time [7, 22, 40, 42, 61, 68]. Metacognitive interventions are typically facilitated by using self-reflection prompts which can be delivered using handouts in a classroom, a virtual cognitive tutor, or by using verbal prompts presented by an instructor or computer program during training; [7, 40, 61, 68]. Metacognitive interventions have the potential to increase learner engagement by improving self-efficacy [22, 61] and task value [40]. However, research has shown that this type of intervention interacts with an individual's goal orientation, wherein it may only be beneficial for individuals who aim to perform well, and may decrease performance for individuals who avoid situations where they may perform poorly.

Metacognitive Interventions and Traditional Learning Environments. Metacognitive interventions have led to improved learning strategies, understanding and academic success in traditional environments [7, 42, 49]. Kramarski and Mevarech [42] found that metacognitive training where students were presented with self-addressed metacognitive questions during tasks (e.g., "what strategy is most appropriate for this task?") improved students' ability to create graphs and improved transfer of knowledge from learning to performing. Askell-Williams et al. [7] evaluated students existing levels of metacognitive activity and implemented metacognitive strategies where teachers gave verbal prompts focused on identifying key ideas, strategy instruction, and monitoring understanding. Students were also asked what the topic was about, what strategies they would use, to draw concept maps of the topic, and write key points of the lesson and what they did not understand. Over the course of the class it was found that students improved learning strategies.

Metacognitive Interventions and Virtual Learning Environments. Metacognitive interventions led to improved knowledge and understanding in virtual environments [5, 27, 40]. Ford et al. [27] measured metacognitive activity with complex decision tasks, such as radar operations, and discovered metacognitive activity related to improved knowledge acquisition, performance, and self-efficacy. Vincent and Koedinger [68] evaluated the outcomes of using a virtual cognitive tutor in a computer math program to prompt students to engage in self-explanation and exhibited better visual and verbal declarative knowledge, more in-depth procedural knowledge, and better transfer of knowledge. Kohler [40] evaluated the effects of metacognitive intervention with second language learners by using a computer-based learning program that prompted students with self-reflection questions. It was found those in the metacognitive intervention condition had higher perceived training value; exhibited increased comprehension; and mastery of vocabulary, speaking, and listening of the language. Downing et al. [22] was interested in how metacognition was affected by different learning styles. Researchers measured undergraduate student's perceptions of their thinking or metacognitive development and performance in problem-based learning (PBL) and non-PBL classes. PBL students had higher metacognitive ability, which led to higher self-efficacy. Metacognitive activity improved in those high in mastery goal orientation.

Metacognitive Interventions and Embedded Learning Environments. Metacognitive interventions have led to improved knowledge and performance in embedded environments [61]. Schmidt and Ford [61] used display prompts to facilitate metacognitive learning for students learning how to design webpages. Metacognitive intervention was administered through having students reflect on learning and encouraging them to go back and revisit material if not fully understood. Students exposed to metacognition had higher declarative knowledge, training performance, self-efficacy, and time efficiency. Additionally, the metacognitive interventions were more beneficial for individuals high in performance-approach goal orientation, compared to individuals high in performance-avoidance goal orientation whom such strategies may actually lead to lower knowledge acquisition.

2.2 Challenge Level Optimization

Optimizing challenge to an individual's skill level can increase learning, performance, and motivation—even when the perceived difficulty is lower than desired. The primary learning context in which challenge optimization has been used successfully is virtual environments. Increasing challenge in a simulation is one of the important factors for effective training and skill mastery [38]. Challenge can be optimized through target difficulty, making enemies more skilled, among other factors. Simulator difficulty must be comparable to reality for challenge level optimization to be beneficial [11].

Challenge that adapts to one's skill may be best suited for individuals with high openness and neuroticism. Individuals low in these traits may be better suited for static difficulty [11]. Individuals without experience in video games/simulations may do best with static/adaptive difficulty [11, 60].

Challenge Level Optimization and Virtual Learning Environments. Within virtual learning environments, challenge level optimization has led to higher learning and performance. The extent of the benefits can be different based on personality, medium of challenge level optimization, and experience in simulated environments. Sampayos-Vargas et al. [60] compared 3 different mediums for learning Spanish (i.e., word matching, fixed difficulty game, and adaptive difficulty game). Motivation stayed constant across the conditions; learning and performance increased for the adaptive difficulty game. Sampayos-Vargas et al. [60] also found that fixed and adaptive difficulty simulated Spanish games resulted in higher perceived competence. Bauer, Brusso, and Orvis [11] researched adaptive difficulty in a military simulation game. The game asks trainees to find intel on enemy soldiers while being exposed to increasing, static, or adaptive difficulty (i.e., difficulty remains the same, increases, or increases/decreases based on performance, respectively) by making enemies more skilled and damaging. High openness and high neuroticism individuals performed better under adaptive difficulty while those with low openness did better with static or increasing difficulty and low neuroticism with static difficulty. Orvis et al. [50] evaluated performance and motivation in a military shooting training game. Performance and motivation increased regardless of the difficulty condition. Participants without prior gaming experience performed best under adaptive or no difficulty adjustment, whereas, those with gaming experience improved equally under all conditions.

2.3 Goal Clarity

Goal clarity has resulted in improved learning, performance and presence in a range of learning environments [12, 15, 46, 62]. Goal clarity has resulted in higher motivation in the classroom [62], but may not improve performance for those with low motivation [15]. Goal clarity can be varied by the method in which goals are presented (e.g., consist goals from managers and colleagues, clear deliverables, or by adding audio in a simulation; [12, 46]). Goal clarity may not benefit those in highly autonomous live training unless they have prior experience [12].

Goal Clarity and Traditional Learning Environments. Seidel et al. [62] found that students had increased competence and higher self-determined motivation (i.e. intrinsic, identified instead of externally motivated) when presented with high goal clarity/coherence videos. Students were presented various videos in a physics course with high and low goal clarity and coherence with lessons. Students viewed high goal clarity/coherence lessons as more supportive environments. No change in interest was found as a result of goal clarity in the classroom.

Goal Clarity and Virtual Learning Environments. Within online virtual environments, goal clarity has led to increased learning, perception of learning, learner presence, and positive perception of instructors when presented in a multimodal medium. Goal clarity can improve performance for those with high motivation to think deeply about lessons. Limperos et al. [46] presented a brief online lecture on flow theory both the clarity of goals and delivery modality. The visual and auditory conditions resulted in improvements in: actual and perceived learning, presence, perception of the instructor's credibility, goodwill, and competence. The results support the notion that adding multimodal CBTs raises overall clarity more than altering content clarity. Bolkan et al. [15] evaluated the effects of goal clarity through a video-based communication studies lecture. Goal clarity was manipulated by providing elements such as advanced organizers. It was found that goal clarity interacted with motivation to learn. Those with high goal clarity and motivation to think deeply had increased test performance; those who had low motivation did not.

Goal Clarity and Embedded Learning Environments. Goal clarity has improved learning for those with prior experience in autonomous work environments. Beenen and Mrousseau [12] surveyed MBA interns during their internships on goal clarity, autonomy, prior experience, learning, and job acceptance intention. Goal clarity accounted for 15.5% of the variance in learning and significantly correlated with job acceptance intentions. Beenen and Mrousseau [12] suggest establishing high goal clarity by ensuring goals are consistent from all managers and colleagues and can be achieved by clear deliverables. Goal clarity may not benefit those in highly autonomous training unless they have prior experience [12].

2.4 Feedback

Providing process level feedback (i.e., feedback on the individuals methods for task completion) as opposed to performance level feedback (i.e., how well/poorly they performed) can result in improved performance perception, learning outcomes, improved strategies, effort, self-confidence, competence and engagement [17, 23, 70]. Feedback can also be delivered through various methods (e.g., simulator, instructor; [17, 38, 70]). However, providing only performance level feedback can cause competence to decrease [70].

Feedback and Traditional Learning Environments. Wollenschlager et al. [70] evaluated the effects of different feedback types in a science classroom. Students planned scientific experiments within three feedback conditions: (1) received grades on the overall assignment (2) received feedback on each aspect of a rubric on a grade of one to five, (3) others marked where they did well and where they could improve on the next scientific plan assignment. Students rated what they believed they would receive before actually getting their grade. It was found that improvement feedback resulted in higher perceived task improvement and more accurate expected outcomes, however no change in interest was seen. Solely providing performance feedback or transparency information can lead to perceived competence to decrease. A study by Gan, Nang, and Mu [29] explored what classroom feedback practices trainee teachers experience, and how their feedback experiences relate to learning motivation. The study found that activity-based feedback, teacher evaluation feedback, peer/self-feedback and longitudinal-development feedback led to motivational increases. Peer/self and longitudinal-development feedback were the most powerful.

Feedback and Virtual Learning Environments. Earley et al. [23] studied a simulated stock market exercise to evaluate the effects of goal setting and process/outcome feedback on performance and other outcome variables. Process level feedback related to goal setting, improved task strategies, and information search. Outcome feedback (in combination with goal setting) improved effort. The authors noted that challenging goals in combination with high process and outcome feedback resulted in the highest performance. Earley et al.'s [23] study also revealed outcome feedback and goal setting can result in improved self-confidence. Issenberg et al. [38] performed a meta-analysis of medical simulators finding that feedback during the learning experience was the highest contributing factor to effective learning. Chapman, Selvarajah, and Webster [17] evaluated a computer based training program on motivating employees in three conditions: text, audio with images, and video. The video condition resulted in higher perceived feedback and in turn highest engagement.

2.5 Autonomous Self-regulated Learning

Self-regulated learning allows for a more autonomous environment, where offering choice allows an individual to repeat a task until learning is achieved [38, 57] or regulate the difficulty [43] to achieve mastery [33]. Self-regulated learning can result in increased motivation; achievement, performance, engagement and improved retention [19–21, 33, 43, 57, 67]. Self-regulated learning is commonly stimulated through choices (e.g., allowing learners to pick the assignments or trainings they wish to pursue [21]) and variability in availability (e.g., when to complete assignments; [38]). However, those with low understanding [57] experience [12], and beliefs (i.e., self-efficacy) may not perform well under highly self-regulated learning environments.

Autonomous Self-regulated Learning and Traditional Learning Environments. In traditional learning environments, self-regulated learning can result in higher academic achievement, intrinsic motivation, engagement and improved skills in enhancing self-learning techniques. Rotgans and Schmidt [57] examined how autonomy in PBL within classroom environments affects cognitive engagement. Their findings were consistent with increased cognitive engagement and higher academic achievement. However, autonomy seemed to be largely dependent on student's understanding of the topic. Deci, Vallerand, Pelletier, and Ryan [21] found that students who perceived their professors or environment as autonomy supportive had higher levels of intrinsic motivation. Those who felt they understood what controls the outcomes in school were rated as more engaged in school by their teachers and had higher achievement as shown by grades, when compared to those with less control understanding. Gillard, Gillard, and Pratt [33] induced autonomy through choices, mastery, and purpose. Survey findings and grades supported Gillard's belief that students who are given more choice become more motivated to work towards mastery of a subject compared to more structured environments. Cleary and Zimmerman [19] trained high school volleyball students in multiple self-regulated learning processes including, perceived instrumentality and task interest (forethought), self-monitoring (performance), and self-evaluation (self-reflection). The outcome was improved performance, engagement, and greater achievement. Initiation and sustained self-regulated learning is largely dependent on self-motivation beliefs such as self-efficacy, outcome expectations, task interest, and goal orientation.

Autonomous Self-regulated Learning and Virtual Learning Environments. Leiker et al. [43] evaluated the effects on performance and motivation on a motion-based video game through adaptive difficulty. Participants were either given the ability to (1) choose to raise or lower difficulty or (2) difficulty was selected for the participant. Those in the choice condition exhibited higher retention and intrinsic motivation. No effect on motivation and engagement was found. Issenberg et al. [38] performed a meta-analysis of reports on medical simulators finding that allowing simulators to be available at any time allows for repetitive training. Availability was found to be the second most important factor in effective training.

Autonomous Self-regulated Learning and Embedded Learning Environments. In embedded learning environments, autonomous self-regulated learning can lead to increases in performance, learning, and intrinsic motivation. Curado et al. [20] reviewed multiple studies where employees were either given the choice to enroll in training of their choice or were assigned to training. They found that when a job offers choice to employees on which training to participate in, they performed better. Hicks and Klimoski [35] conducted a study in which a company's managers were either assigned to a training session or given choice. At the end of the training session those in the choice group showed an increase in learning, motivation and satisfaction compared to the assigned group. Thomas and Velthouse [67] conducted a literature review and found that four task assessment dimensions were important to engagement (impact, competence, meaningfulness and choice). Freedom in choices leads to a more intrinsically motivated individual, creativity, initiative, resiliency, and self-regulation.

2.6 Personalization

Personalizing content to an individual's interests can result in increased engagement, learning, effort, and situational interest [13, 26, 34, 36]. Personalization can be achieved through content manipulation such as tailoring problems to topics of interest or through creating games related to the lesson [13, 34, 36]. Personalizing content can trigger situational interest, which is not long lasting [13] yet can be maintained and increased through repeated exposure [36].

Personalization and Traditional Learning Environments. In traditional learning environments, personalization can lead to improvements in engagement during task performance, triggering and maintenance of interest, enhanced learning, and lower mental effort. Fives and Manning [26] conducted a study on teachers' knowledge of research-endorsed-motivational strategies for student engagement. The study found that incorporating student's interests and values can lead to improved task engagement. Hidi and Renninger [36] proposed a 4-phase model of interest development in learning from a review of the literature, finding that when interest is captured it can lead to seeking for challenge and goals related to a task. Engaging activities (e.g., games) can trigger interest while involved tasks, (e.g., group projects) can maintain and build individual interest. Ginns & Fraser [34] examined whether the personalization of paper-based instructional materials through modified text (i.e., writing instructional text to address the learner directly while emphasizing personal relevance) would enhance learning heart terminology. Findings indicated that personalization enhanced learning, and lowered ratings of mental effort during testing indicating deeper learning. Personalization did not lead to higher levels of interest and enjoyment.

Personalization and Virtual Learning Environments. Bernacki and Walkington [13] used a math tutoring program (i.e., Cognitive Tutor Algebra) in conjunction with a survey on interests to personalize math problems to topic areas participants were interested in (e.g., music, TV, sports). Participants in the personalization group displayed more meaningfulness and in turn a heightened situational interest. Ambroziak, Ibrahim, Marshall, and Kelling [6] assessed the use of the simulation program, MyDispense which allowed students to personalize skills trained. Students generally perceived the virtual simulation as an effective tool for learning medication dispensing skills. However, a drawback of the personalized simulated environment was the amount of time it took to create and test the personalized exercises.

2.7 Experiential Learning

Experiential learning can lead to higher engagement levels, knowledge gains, and knowledge retention [28, 66]. Experiential learning is commonly facilitated through PBL and inquiry-based learning (IBL). Increased task time can result from learning by doing and is not suggested with difficult learning material as the cognitive load may be too high for students attempting to develop an initial knowledge foundation [66].

Experiential Learning in Traditional Learning Environments. A study conducted by Ahlfeldt, Mehta, and Sellnow [3] measured student engagement across fifty-six university classes where some of the classes consisted of teachers trained on PBL. Higher levels of engagement were experienced in smaller classes, classes with teachers who had the most PBL training, and classes with teachers who implemented more PBL strategies [3]. This is consistent with other researchers who have found higher levels of engagement from PBL environments [28, 37]. Hmelo-Silver, Duncan, and Chinn [37] conducted a review of the literature on IBL and PBL environments. Their efforts showed that both types of experiential learning can help foster mastery goal orientation and higher knowledge gains. Winsett, Foster, Dearing, and Burch [69] assessed how experiential learning affected engagement in business management students. Higher levels of behavioral, emotional, and out-of-class cognitive engagement resulted from group-based experiential learning. It is important to note that the results suggest experiential learning has specific effects when paired with specific mediums. When paired with group discussions it yields physical engagement; group projects appear to drive emotional engagement; variability in group work drives cognitive out-of-class and emotional engagement.

Experiential Learning in Virtual Environments. Fukuzawa and Boyd [28] created the online Monthly Virtual Mystery game, which provided case-studies to engage learners. Students were divided into two groups either receiving the case studies or having to answer regular discussion board questions. The findings were consistent with PBL leading to higher levels of engagement and higher perceived value in online discussion boards. Students utilizing the game had a higher completion rate demonstrating that an active learning project can be implemented using PBL principles through an online discussion board. However, no difference in learning was found which the researchers attributed to the large class discussion sizes. A literature review by Al-Elq [4] on the use of simulators for experiential learning found that simulators led to improvement in learners' competence and confidence. Al-Elq [4] referenced a study where practitioners practice their life saving skills. Survey results showed that practitioners felt more confident post-experiential learning and that the use of simulators led to higher competence as they allowed for a deeper understanding of complex medical factors.

2.8 Game-Based Learning

Within traditional and virtual learning contexts, game-based learning has led to gains in conceptual, tacit, declarative, procedural, strategic, and knowledge transfer, as well as increased performance, flow, and engagement [2, 10, 39, 45]. Learning activities can be "gamified" by adding incentives and gaming qualities to an activity that may be uninteresting [51]. However, game-based learning can also result in lower explicit knowledge if students become too focused on how to beat the game, which can result in decreased confidence when tested on knowledge gains (Rieber and Noah [54]). Game-based learning can be facilitated by adding gaming elements or developing a game that may include: clear rules/goals and feedback, competitiveness, opportunities to solve problems, uncertain outcomes, or scores [30, 31]. One example is an interactive game-based physics lesson that allows students to control a ball's acceleration and velocity [54]. In game-based learning, the depth of flow may depend on the academic level of the student [2] but has the potential to increase motivation for all students [9, 30, 45, 51]. It should be noted that technological issues can decrease the flow of game-based learning if they become a distraction [2].

Game-Based Learning and Traditional Learning Environments. Game-based learning in the classroom has the potential to increase learning, understanding in how concepts are related, and motivation. Bai, Pan, Hirumi, and Kebritchi [9] utilized game-based learning in mathematics. Students either learned algebra using the game-based DimensionM method or through regular instruction. Students who were in the game-based learning condition had increased mathematical knowledge and maintained motivation to learn when compared to those who did not. A study by Kao, Chiang and Sun [39] utilized game-based learning in a science classroom to teach physics. Participants in game-based learning groups scored higher than those in the no game learning group demonstrating had higher related knowledge. Admiraal, Huizenga, Akkerman, and Dam [2] utilized the game Frequency 1550 to teach history to high school students. The game resulted in students showing a state of flow and improved performance during the game. However, the game did not have any results in learning outcome. The authors propose this is due to the distracting features of the game. A meta-analysis conducted by Li and Tsai [45] of science game-based learning found that it led to improved interest, motivation, and engagement in the classroom.

Game-Based Learning and Virtual Learning Environments. Game-based learning can lead to better performance, deeper learning, and engagement in virtual learning environments. A study conducted by Barab et al. [10] developed a 3D game-based curriculum designed to teach water quality concepts in a simulated environment. Student experienced traditional, framed, or immersive world conditions. The immersive world conditions performed significantly better than traditional learning. A study by Squire and Jan [65] found that incorporating game-based learning in a simulated environment led to increased engagement and deeper learning. A group of students utilized a place-based augmented reality game called Mad City Mystery to learn about diseases. Increased engagement was seen in the form of students revisiting different areas in the game to answer the problem posed by the game.

2.9 Interactivity and Multimedia

Adding interactive elements can increase engagement [1, 14, 41] but can be hindered if the student does not know how to interact with the technology or becomes distracted by features [1]. Interactivity can also result in increased understanding and mastery [1] increased collaborative learning, and increased performance [14]. However, some studies have shown limited learning gains from adding interactive elements [52]. Interactivity is usually accomplished by allowing interaction with an activity or system through feedback, control, simulation, and adaptation. Additionally, interactivity can be achieved by adding more complex mediums such as animations, simulations, or live environments [1, 14, 52, 64]. Adding interactivity to learning activities can increase attention, motivation, confidence, satisfaction, relevance [56] perceptions of learning effectiveness [41], situational interest [52] and enjoyment, but can take away from the other learning aspects if not implemented appropriately [1].

Interactivity and Multimedia in Traditional Learning Environments. Interactivity can lead to improved learning, performance, understanding, and engagement. A study by Blasco-Arcas, Buil, Hernandez-Ortega, and Sese [14] incorporated interactivity by using clickers in a social sciences university classroom. Clickers resulted in increased engagement, collaborative learning, and performance. Krain [41] found that using video format to present case studies and PBL lead to increased engagement and student perception of effectiveness.

Interactivity and Multimedia in Virtual Learning Environments. Within virtual learning environments interactivity and multimedia can led to increases in interest, enjoyment, understanding and mastery. A study conducted by Adams and Reid [1] surveyed two hundred students who were using interactive simulated environments to learn physics, and observed five students utilizing an interactive simulation to create a circuit. Interactivity led to increased understanding, enjoyment, and mastery. However, it is important that the simulated environment be easy to use and the features not be too distracting [1]. A study by Pedra, Mayer, and Albertin [52] utilized interactivity in maintenance video instruction. High interactivity led to increased situational interest, however, no learning outcome gains were seen.

Interactivity and Multimedia in Embedded Learning Environments. Rodgers and Withrow-Thorton [56] were interested in how different instructional media affected learner motivation in a workplace training situation for a hospital. Results indicated that interactive safety training led to increases in attention, satisfaction, and confidence, as well as in motivation.

2.10 Meaningful Learning

Utilizing meaningful learning tactics has resulted in higher engagement [25], achievement [32], understanding, recall, and transfer of knowledge [25, 47]. Meaningful learning can also increase an individual's satisfaction and motivation [55, 63]. However, in some environments, motivation can decrease with the addition of meaningful learning aids such as concept maps, as learners prefer to learn through the more enjoyable means [18]. Decreased motivation can result from adding concept maps in certain areas (e.g., while playing a game to learn history), when more fun ways to learn exist [18].

Meaningful Learning in Traditional Learning Environments. Eppler [25] studied the effects of meaningful learning in a knowledge management and research methods course. Meaningful learning was induced using visual aids such as concept maps, mind maps, visual metaphors, and conceptual diagrams to build knowledge. Students exposed to the visual aids yielded increased engagement, as well as improved understanding, enjoyment, and recall. Gidena and Gebeyhu [32] utilized academic organizers in physics instruction to discern their effects on academic achievement. Academic organizers led to improved academic achievement, knowledge, and understanding. Mayer and Bromage [48] examined how advanced organizers affected learners in understanding a new computer programming language prior to or after learning. Students either read the advanced organizers before reading or after reading. Advanced organizers led to improved transfer of knowledge, connections, and recall but retention of information was not affected. Students in the before group had high recall of conceptual idea units, more appropriate intrusions, and novel inferences. Students who were presented with the advanced organizers after, scored higher on recall of technical idea units, and had less appropriate intrusions, connections, and nonspecific summaries. Shihusa and Keraro [63] investigated the effects of advanced organizers on learner motivation in a biology class to learn about pollution. Advanced organizers led to motivation increases compared to conventional learning experience.

3 Virtual Learning Environment Use Case

We include here a use case example of how a subset of these interventions could be implemented within a virtual surgery simulator course in a medical program. Before the training course, a set of queries could be sent to each trainees via a mobile application to collect demographic and individual trait information known to impact an individual's propensity to become engaged in the learning topic (e.g., personality, self efficacy, interests). The instructor could also send learning material and advanced organizers related to the upcoming simulated surgery to prompt the trainees to cognitively engage in the topic beforehand. The instructor could then review the profiles of each individual prior to the first training session to familiarize themselves with each trainee, including their propensity to become engaged. If a particular learner has low self-efficacy, the instructor could consider providing process level feedback with specific areas of improvement. During the training session, the instructor could monitor performance to determine if the simulated surgery task is too overwhelming or too simplistic for the trainee's level of skill and adjust accordingly. For motivated learners who seem to have developing skill levels, instructor could provide more autonomy by allowing the learner to practice outside of normal training sessions to work toward mastery. If other trainees show boredom and lack of interest, the instructor can tailor the task to individual goals. For example, if an individual learner aims to work in the pediatric field, the instructor can adjust the surgery simulation task so that it targets pediatric emergency care. Instructors can provide process-level feedback regarding performance on the simulated task and utilize metacognitive prompts to promote self-reflection.

4 Implementation Considerations and Conclusion

It is important to consider the environment, individual, and task itself when choosing the instructional intervention to implement as some may be more effective, feasible, or applicable in certain contexts. For instance, challenge/skill optimization is easiest to implement in environments in which there are ongoing assessments of individual learner knowledge/performance, such as in simulation or computer-based learning. Such is the case for feedback, as well. On the contrary, instructors can easily deliver clear goals in a range of environments. In addition, consideration should be given to individual learner characteristics, as some interventions only foster engagement in the right individual. For example, those who are afraid of performing poorly will perform worse under metacognitive interventions. However, those who are not afraid of learning from mistakes and seek to master a task will have improved performance with metacognitive intervention [61]. Additional caution should be taken when combining multiple instructional interventions. Utilizing interventions aimed at increasing the depth of understanding (e.g., concept maps) with interventions aimed at increasing enjoyment (e.g., games) can have a negative effect. Learners may become disengaged when completing the concept maps, as they prefer to engage with the content in the more entertaining way [18]. Consideration must be given to the particular intricacies of each intervention presented above.

5 Conclusion

The modern educational environment is changing the way individuals learn and so must the way we teach. When fashioning learning opportunities to facilitate effective learning, instructors should consider what is the optimal learning environment, the ideal instructional interventions, and students' individual characteristics. There is a wealth of knowledge available in the education and cognitive psychology literature that can be leveraged to achieve this. This paper attempts to facilitate this process, by presenting a taxonomy of instructional interventions that aim to increase learner engagement, mapped to the learning environment in which they have been shown effective in the literature. Also presented are a use case implementation in a virtual environment along with important considerations for implementation. By marrying proven instructional techniques, with emerging and innovative technology, instructors have the opportunity to more fully engage learners in each learning opportunity.

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