TOWARDS AN INSTRUCTIONAL DESIGN METHOD TO DEVELOP M&S SUPPORTED PORT MANAGEMENT INSTRUCTIONS

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ABSTRACT
There are benefits to teaching complex systems using modeling and simulation (M&S) because learners can interact with system representation and conduct experiments that reveal system's behavior. Teachers can use M&S as a backbone of instructional activities, making them more interesting, motivating, and effective than traditional teaching strategies. Although many generic approaches to designing instructions are available they do not always provide the detailed guidelines for designing specific instructional activities supported by M&S. This paper reports on efforts to create an instructional design method (IDM) focused on the Scalable End-to-End Logistics Simulation (SEELS) M&S environment with port management as the subject of instruction. The concepts applied in the proposed IDM can be generalized for M&S-supported learning approaches. IDM will aid instructional designers define instructional content and determine their strategy for developing engaging and effective instructional material supported by constructive M&S.

Keywords: modeling and simulation, instructional design, port management

1. INTRODUCTION

Teachers, such as educators, instructors, lecturers, and faculty members can benefit from using modeling and simulation (M&S) because M&S-based lessons can be interesting, motivating, and effective (Balaban, Russell, Mastaglio, & Dykes, 2016). Using properly designed instructional approaches, students engaged with M&S can tap into the higher cognitive levels of Bloom's taxonomy i.e. analyzing, evaluating and creating. The use of simulation models can support new game-based (Epper, Derryberry, & Jackson, 2012) and collaborative project-based (Bell, 2010) instructional strategies. Students can conduct experiments relevant to real world problems and learn problem solving skills using M&S. Students generate results of experiments using simulation models, which provide them with direct feedback on their decisions and planning solutions. M&S can offer teachers a whole new set of instructional strategies and evaluation mechanisms. M&S should allow design of appropriate strategy for instructions targeting both analogical and adaptive transfer. The development of computer-generated models of seaports and their main components, like terminals, operational areas and resources – as the ones proposed in Longo (2012) and Bruzzone and Longo (2013) – ensures that students understand both structure and operations. Modeling and simulation (M&S) of proposed designs, concepts, or changes that could be made to a port enables proactive thinking (Balaban et al., 2016). This must be supported by a highly usable M&S tool that presents relevant information and hides unnecessary details. Moreover, teachers should be able to improve instruction based on their teaching experience and evaluation of student performance using M&S artifacts. Teachers may consider adding new activities, changing sequence of activities, and improve the content of activities by adding new concepts and new M&S scenarios. A flexible and reconfigurable M&S environment should support new exercises related to advancements within the area of study so teachers can easier improve their curricula.

Designing instruction for teaching complex concepts can be difficult and time consuming (Jonassen, 1997). Epper et al. (2012) pointed out that most games and simulations are too narrow to allow widespread adoption at multiple institutions. Moreover, general M&S software requires highly specialized knowledge, often beyond a teacher's expertise. If the learning curve is high this may inhibit the use of M&S as supporting materials. There would have to be a person involved who knows how to use specific M&S artifacts to implement supporting materials. On the other hand, if the learning curve is low teachers will be able to develop M&S materials themselves. Jonassen (1997) pointed out that although generic recommendations for simulation and other problem-solution types of instruction are available, no instructional design guidelines explain how to design specific components of instructions. This can significantly inhibit adoption of M&S in educational settings. Supporting M&S artifacts must be easy to implement and tailorable in the context of required instructions. Finding balance between functionality, usability, flexibility and effort when developing content using M&S environment is very important. Moreover, although a number of instructional design approaches are available they fall short in the context of providing guidelines to design instructions supported by M&S, especially within industry specific fields.

This paper looks into how to empower an instructional designer, who may be also a teacher, to facilitate development of port management lessons supported by the SEELS environment. Balaban et al. (2016) proposed technical approach to developing M&S based lessons, but more specific guidelines are needed. This initial effort to create IMD considers constructive M&S for designing and developing more engaging and effective instructional materials. The development of an M&S-based IDM is bottom-up, focusing on a particular M&S environment and knowledge domain, but its elements can be generalized to serve a broader M&S worldview. The words student and learner are considered synonymous in this paper.

2. INSTRUCTIONAL DESIGN: BACKGROUND

Instructional design can be defined as a systematic and reflective process of translating principles of learning and instruction into plans for instructional materials, activities, information resources, and evaluation (Smith & Ragan, 1999). This section briefly introduces selected instructional design models and their limitations in the context of developing M&S supported lessons. Although IDMs are commonly called models, this work labels them as methods. This is assumed by following M&S convention where a method is used to develop a model (Balaban, 2015). Using this parallel, IDM is used to develop units of instruction.

2.1. Generic instructional design methods

This subsection provides an overview of IDMs as an initial point of discussion. Molenda (2003) investigated the origins of Analysis, Design, Development, Implementation, and Evaluation (ADDIE) method and noted that this term is used as an umbrella of instructional design approaches with over 100 different variations. It originally consisted of four phases; objectives, pretest, instruction, and posttest, as well as a looping process for revision purposes. It was an adaptation of a system engineering process for problems associated with workplace training and instruction. Over the course of time, the method has been revised to include the current five ADDIE phases. Evaluation is a key provision that takes place in every phase. While the behavioral aspect handled procedural tasks, the addition of cognitive theoretical underpinnings addressed nonprocedural tasks (2006). Dick, Carey, and Carey (2001) proposed well-defined steps in an iterative cycle, providing more granular view of the steps as compared to ADDIE. They proposed separate steps for specifying learner entry behavior and instruction characteristics, both directing toward objectives. Similarly Kemp, Morrison, and Ross (2004) provided a more detailed view of iterative phases, but characterized by unspecified order of steps to facilitate more flexibility in developing instructions and emphasized the importance of management of instructional design. Others proposed simplifying the instructional design into just three phases emphasizing iterative characteristic, importance of understanding, agility, and collaboration (M. Allen & Sites, 2012; Piskurich, 2015; Wiggins & McTighe, 2005). A different focus for instructional design was offered by Pearson and Gallagher (1983) who proposed the level of student independence as a guiding principle. The approach originated with a focus on the reading skills but it could be used more broadly. It has four phases:

1. demonstration, where teacher delivers instructions,
2. guided instruction, where teacher leads students through instructions.
3. collaborative learning, based on group activities, and
4. independent student practice (Fisher, 2008; Fisher & Frey, 2013).

All presented IDMs have provided important guidelines, but they do not include elements critical to supporting M&S-based instructions. In order to facilitate delivering instruction using M&S environments, the instructional designer or teachers themselves must acquire sufficient M&S knowledge to develop the learning activities. A new perspective on what IDM is and how it should guide development is needed; one that incorporates translating instructional activities into M&S activities and that is in a form that can be applied by those not proficient in M&S.

2.2. Levels of IDM for M&S supported lessons

Honey and Hilton (2011) proposed a research agenda for simulations and games in learning science where they pointed at the need to research design features, methodologies, and their links to learning outcomes. Depending on their purposes IDMs for M&S could be specified at different levels as defined by their universality and precision (Popper, 2002). Figure 1 demonstrates this based on the example of four IDMs starting from a more universal and less precise approach at the top of the graph to more precise and less universal at the bottom.

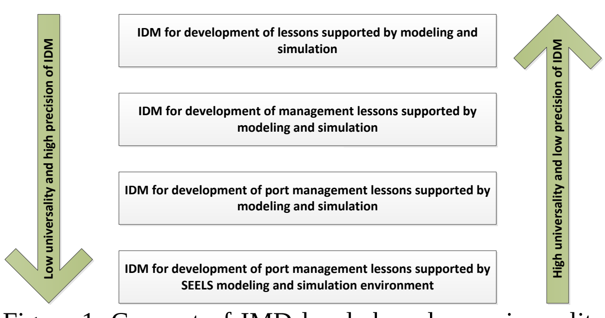

Figure 1. Concept of IMD levels based on universality and precision

The top type of IDM should be used when no low level IDMs exist and the instructor designer has M&S expertise. This level may also be sufficient when more precise guidelines do not benefit teachers because the subject area is well-established and general, and a set of existing simulation models with detailed instructions can be obtained to support lessons. On the other hand, more specific IDMs would be beneficial to instructional designers without M&S expertise and for those topics related to specific knowledge and skills that have not been widely explored using M&S and for which there is not easy access to supporting M&S materials.

The existence of IDMs for a specific knowledge domain and relevant M&S tools can aid development of more advanced and specific lessons. For instance, if the IDM provides guidelines specific to both port management and SEELS it could offer more specific mapping between learning objectives, business objectives, and M&S objectives. On the other hand, this view is a simplification relative to the current state of the art of IDMs. The benefits related to the specification of the knowledge area within IDM may be discounted in the future, making both universal and precise IDMs possible by providing sufficient guidelines across broader areas of knowledge and a more general M&S view. The second level from the top in Figure 1 shows generalization across for both management and M&S views, while the top level IDM shows implicit generalization of knowledge domains under the M&S umbrella. This paper can be placed at the bottom level of Figure 1. The specific goal is to propose IDM guidelines focused on port management instructions supported by SEELS environment. Based on this work a more general IDM for M&S could be also derived in the future.

3. IDM FOR PORT MANAGEMENT SUPPORTED BY SEELS

A developed model of an instructional unit is the main product of IDM. The instructional unit specifies types of activates, that including assessment activates, their sequence, and supporting materials. A traditional lesson as a unit of instruction would consist of both class and home activities. Depending on type of delivery, e.g. class, online or mixed, teachers may consider different activities and levels of control over instruction. Activities can also be characterized by the type of feedback from learners, level of learner's control, level of interaction between students, and Bloom's taxonomy level.

3.1. The purpose of M&S based IDM

Instructional design facilitates guidelines that help to develop effective and appealing instructions that require minimum time to learn concepts (Smith & Ragan, 1999) and minimize time to produce instructions. Instructional design may involve many collaborators, e.g., instructional designers, M&S developers, and teachers. It is possible for single faculty members to perform all three roles. If subject matter experts (SME) are tasked to develop an M&S-based port management curriculum, they need to learn IDM and M&S. If instructional designers are tasked to develop it, they need to learn the subject area, e.g., port management and M&S. It is common in a university setting that faculty members along with their graduate students develop or improve curricula. They may have some expertise in both instructional design and a subject. This helps because only additional M&S expertise is needed. IDM aims to be sufficiently generic, with the respect to the role of instructional designer and developer, so it only assumes that the person designing instructions and developing instructional materials follows the IDM, has access to domain knowledge, and has access to M&S resources. IDM guides selection of instructional and assessment activities, their scaffolding in sequence, and implementation of instructional material as necessary. The aim of M&S based IDM guidelines is to empower instructional designer to design M&S-based instructions and guide them in developing or reconfiguring M&S materials.

M&S is a broad discipline and knowing what type of M&S capability may be more applicable in the context of designing instructions for a particular domain can be challenging for faculties not experienced in M&S. Because of that M&-based IDM should facilitate guidelines sufficient for successful use of M&S capabilities. To design engaging and effective lessons, the use of capable M&S environment tailored to a particular field is important. The selection of instructional activities and their sequence should be supported by scaffolding principles. Engaging and effective instructions that gradually move control over learning process to students should facilitate the right amount of interaction between teacher and students, amongst students, and between the student and M&S artifacts. Moreover, teachers should specify appropriate communication channels for situations when students face challenges beyond their current capacity. This will ensure that students can keep up with the pace of instructions. The activities should consist of assessment mechanisms which inform teachers about their effectiveness, and help improve instructional activities.

3.2. Overview of the proposed IDM

Figure 2 shows main steps of the proposed M&S-based IDM. It consists of 7 main steps. Steps 4 and 5 contain iterative sub-steps.

3.2.1. Initial assumptions

In this step one should list initial assumptions about an instruction that will be developed including the unit of instruction, e.g. a weekly lesson, type of delivery, e.g. class, online or mixed, assumed students' weekly time-effort, and in-class time constraints, e.g., 90-minute class meeting. A set of instructional units can comprise higher order units such as course curricula.

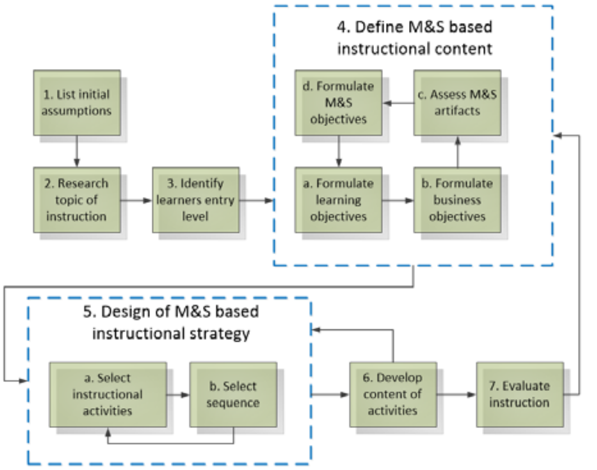

Figure 2. Proposed steps of M&S based IDM

3.2.2. Researching about a topic of instruction

In this step instructional designer identifies scope of the instruction by gathering and organizing resources other than M&S artifacts e.g. book chapters, papers, web articles, and videos. The port management area of expertise is large, but has defined disciplinary boundaries (Alderton, 2013; Bichou, 2014; Song & Panayides, 2012). Making an ordered list of main concepts within a unit of instruction, e.g., port structure, terminal configuration, container processing, and berth occupancy ratio will allow one to better conceptualize the structure of the content. The list should include all the knowledge and skills students should acquire in relation to the selected concepts by the end of a particular unit of instruction specified at the desired level of Bloom's taxonomy.

3.2.3. Identifying learners' entry level

Instruction of complex and advanced concepts related to port management often requires learning both general and specific prerequisite knowledge and skills. The learners' entry level to a course pertains to their educational background and their exposure to the industry. The learners' entry level for each unit of instruction is related to the progression through the curriculum, where the instructional designer should be able to estimate already acquired knowledge and M&S skills from completion of previously introduced units.

If students are or were employed in the relevant maritime industry, they may pursue advanced degrees to advance their careers. They may already be SMEs in many of the concepts and skills covered within a course. These students will differ from entry-level students, which can pose challenges to properly pace instructions in order to keep all students engaged but not overloaded. Properly designed instruction should be able to take advantage of the SMEs and increase amount of time spent on collaborative activities, making sure to divide SME students into separate groups. Before the beginning a semester, faculty should assess learners' entry level to identify and properly 'allocate' SME students.

Identifying each learners' entry level at the beginning of a unit of instruction, e.g. a lesson, allows the instructor to select the applicable activities which support learning at the desired Bloom's level. The difference between desirable level and entry level identifies the gap that should be closed, provides an input to the content definition and strategy design, and establishes a baseline for evaluation.

3.2.4. Defining M&S based instructional content

In this iterative step the proposed content is systematically analyzed. In order to define instructions that include M&S requires identifying three types of objectives: learning objectives, business objectives, and M&S objectives. Figure 3 displays the relationship between learning objectives, business objectives and M&S objectives. Based on the desired Bloom's level specified in step 2 concepts will be used to specify knowledge and skills and write learning objectives. Learning objectives will be examined from the business perspectives. Both, learning and business objectives will in turn provide input for writing M&S objectives, which are used in the next step: designing of M&S-based instructional strategy.

Figure 3. Relations between learning, business and M&S objectives

Formulating learning objectives

Learning objectives are the main components of a unit of instruction, e.g., a lesson. It is defined here as a statement describing intent of instruction in terms of learners' Bloom's level that will be achieved by the end of the instruction. Next one must identify the main components of learning objectives include the learner, the concept to be learnt, the time required (or available) for the instruction, and a verb indicating which Bloom's level will be achieved. Figure 4 provides an example of learning objectives with main components color-coded.

Formulating business objectives

The business objectives link instructions and the real world. One learning objective may consist of zero or more business objectives. Business perspectives can be particularly useful in the context of teaching port management.

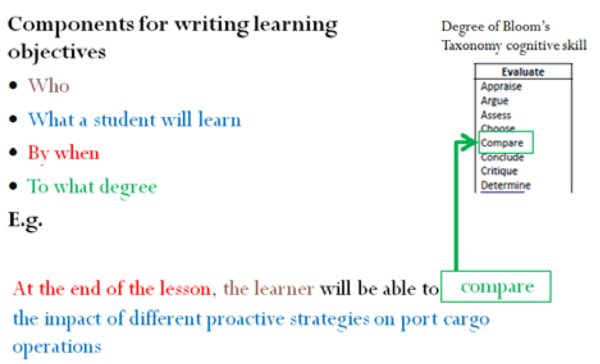

Figure 4. Writing learning objectives

If possible, the educational goal should include concurrent and emergent problems in the industry understanding of which will better prepare students for the job. In general, business problems are mapped to produce evidence supporting a decision. For instance, in the port management business objectives are perspectives that port managers experience. This provides for teaching students relevant problem-solving and decision-making skills. Lagoudis (2012) identified research gaps in the container terminal industry and specified a set of problem categories. Based on an extensive literature review he identified methods used within each category, e.g., mathematics and operations research, management and economics, simulation, and stochastic. Balaban et al. (2016) used a general *problem – decision* concept approach where M&S is used as a problem remediation method. Figure 5 represents the relationship between business objectives and M&S objectives using transition points.

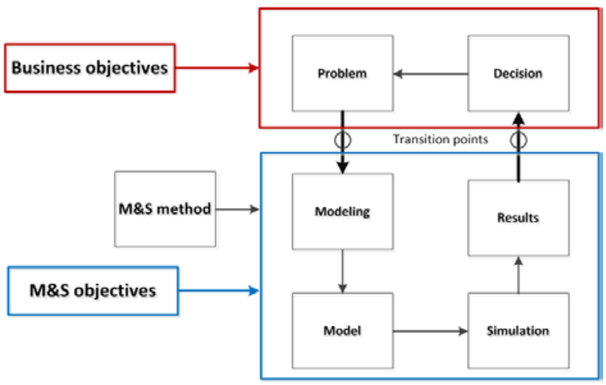

Figure 5. Division of business and M&S objectives within problem – decision space

Business objectives include a problem space and a decision space. Problem space is translated using M&S method into M&S components, which are applied to produce results translated back into decision-making within the business objectives area. Although an M&S method was used, other methods can be also used either in place of M&S or in combination with M&S. Figure 6 provides an example of business objectives with main components color-coded.

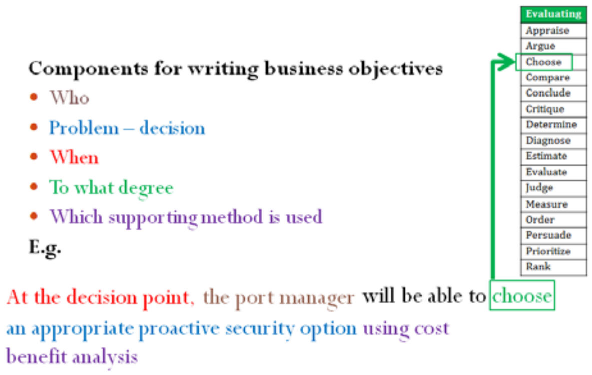

Figure 6. Writing business objectives

Assessing M&S artifacts

In order to determine the appropriateness of M&S to support specific learning and business objectives the supporting M&S environment should be analyzed to assess its capability to cover the targeted concepts. Usually, M&S environments have specific M&S artifacts. Although more generic M&S tools often provide a common set of artifacts, SEELS in its current state is focused on analysis of logistical networks of cargo ports. The following subsection introduces main SEELS artifacts, which will be used during the development of M&S objectives.

SEELS enables representation of a logistical network that can be composed of multiple cargo ports. A network of seaports can be represented with their hierarchal structure that consists of multiple terminal areas, which in turn consist of operational areas. The following are the main M&S artifacts of SEELS environment:

Actor is an M&S artifact with specific characteristics and functions:

- Cargo are goods, e.g., containers, vehicles, people, and bulk. Cargo are carried by the transports or resources.
- Transports move cargo, e.g., container ships, trains, and tucks.
- Port resource is equipment or personnel used to process cargo and transports within a port or terminal, e.g., container cranes, straddle carriers, pumps, and line handlers.

Area is an M&S artifact that serves as a structural building block for a model, e.g., port, terminal, berth, staging area, gate, and inspection station. Changes made to one area affect output factors for that area, other connected areas, and not directly connected areas because of cascading effects. The greater the number of areas involved, the higher the level of cognitive burden imposed on the learner due to increasing numbers of connections and related dependencies. On the other hand, more areas can provide more realistic scenarios, and more challenging problems can be designed.

Profile is an M&S artifact that defines a complete set of transports and cargo loads for a logistical network consisting of a single or many ports and terminals. Profiles describe a schedule of transports, transport quantity, destination of each cargo load associated with each individual transport, among other characteristics. Transports can arrive empty or loaded with a mix of cargo headed for different destinations (Mathew, Mastaglio, & Lewis, 2012). We recommend logically dividing transports and cargo loads into multiple profiles.

Process is an M&S artifact that defines handling of transport and cargo within an area. They are used to capture business rules of ports, terminals, and operational areas. SEELS processes are handled as input data allowing for ease of modification during experimentation.

Input factor is an M&S artifact used to specify characteristics of other M&S artifacts, e.g., process times within an area, route time between areas, quantity of resources, physical attributes such as length, weight, and area, and arrival times.

Programmatic event is an M&S artifact which impacts *input factors* at simulation run-time.

Output factor is an M&S artifact that represents a particular business concern often closely related to business objectives, e.g., throughput, turnaround, utilization, footprint, and cost.

A simulation scenario can consist of multiple profiles, which can be mixed and configured to work with one of multiple network configurations in order to experiment with different structures and varying resources providing end users experimental flexibility. See (Mathew, Leathrum, Mazumdar, Frith, & Joines, 2005; Mathew et al., 2012) for more information about SEELS environment.

Formulating M&S objectives

M&S objectives are the base with which problems can be represented and the decision-making within business objectives can be supported and explained. The M&S environment can be also used to explain concepts within learning objectives, but which do not have relevant business objectives.

Based on the coverage of learning and business objectives by M&S artifacts, an instructional designer can analyze when and how to use M&S to formulate M&S objectives. M&S objectives within the scope of constructive M&S can be characterized by various components of M&S methodology, e.g. conceptual modeling, design of experiment, and simulation output analysis. These components in turn use M&S artifacts, which are more or less specific to an M&S environment. Based on the list of SEELS artifacts, the instructional designer can assess their coverage related to learning, business, and M&S objectives based on the following ordinal scale: full coverage, significant coverage, medium coverage, low coverage, and no coverage. The end result can be displayed in a table or as a graph. For instance, a radar chart shown in Figure 7 displays an example coverage of learning objectives, business objectives, and M&S objectives using SEELS artifacts. It informs the instructional designer about possible partial M&S coverage, and the necessity to complement M&S activities with other activities to ensure full coverage of concepts not already covered.

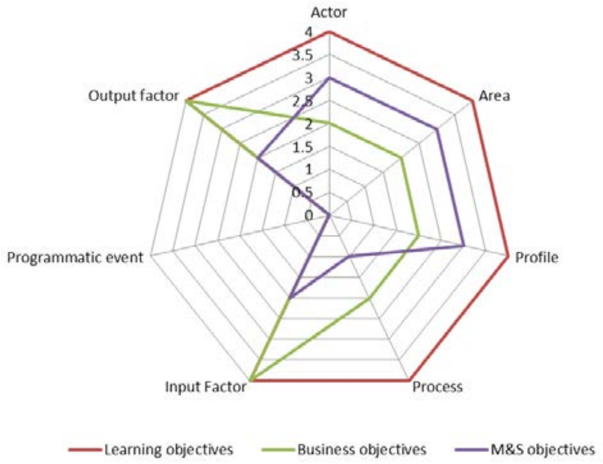

Figure 7. Coverage by M&S artifacts

Figure 8 provides an example of M&S objectives with main components color-coded.

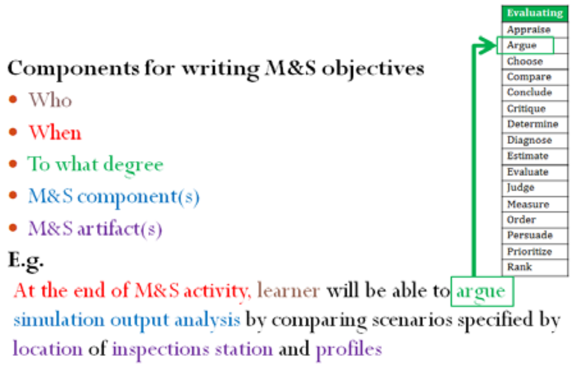

Figure 8. Writing M&S objectives

3.2.5. Design of M&S based instructional strategy

In order to design M&S-based instructional strategy M&S components and M&S artifacts must be allocated to activities as instructional media ensuring learning tasks and assessment are congruent with one another. This section introduces M&S instructional activities. They are briefly discussed with the intention of providing a future research agenda. After introducing M&S-based instructional activities we discuss the initial guidelines on selecting and sequencing them.

M&S based instructional activities

M&S activities are created by adding an M&S component to traditional instructional activities. They are the building blocks of instructional units. Constructive M&S activates require M&S software. For those activities that require sharing the screen of a computer with the rest of the class, a projector or other form of broadcast media is required. In addition to M&S materials, M&S activities can be supported by most traditional teaching materials, such as articles, textbooks, video tutorials, and web content.

M&S lecture involves using M&S artifacts in a one-way transmission of information from a teacher to students. The teacher explains a topic to students switching between M&S artifacts and presentation slides. *M&S lecture* requires minimal student knowledge and skills: it aligns well with lower Bloom's levels facilitating learners' recall and understanding of the topic.

M&S individual laboratory is an activity that involves using M&S artifacts with the teacher gradually moving control of the instruction to students. The instruction is presented in steps supported by working with a number of M&S artifacts. Each students works separately. First, students learn how to complete simple M&S objectives by following a teacher's demonstration and/or tutorials. Then, a teacher leads students through a combination of M&S objectives to achieve a level of student ability to aggregate M&S objectives and to accomplish the business and learning objectives. *M&S individual laboratory* is more appropriate at higher Bloom levels, such as understanding and beyond.

M&S group laboratory is a collaborative activity where students work in groups, using shared knowledge and M&S artifacts to accomplish business objectives. This activity can be extended using a game mode, e.g., groups compete or collaborate, students within group compete or collaborate, or a mixed mode of both competition and collaboration at various levels of group/student. *M&S group laboratory* is more appropriate at Bloom's levels such as apply and beyond.

M&S discussion session is an activity that uses M&S artifacts to transmit information bi-directionally, between students. The teacher defines the scope, facilitates discussion, and monitors the direction of the session. During discussions students can propose alternative ideas and critique potential solutions, which then can be implemented, analyzed and evaluated using M&S thus providing immediate feedback of the proposed ideas and decisions. Students use M&S artifacts to implement their ideas. *M&S discussion session* can be used at many Bloom's levels, which depends on the desired scope defined by the instruction. It provides formative evaluation insight about students' Bloom's level related to the concepts being taught.

M&S student presentation is an activity where an individual student presents to their class using M&S artifacts. Student assume a teacher's role, with a limited control over the instruction. *M&S student presentation* supports different Bloom levels, depending on a student's expertise about the topic. This activity supports formative evaluation.

M&S individual question session is an activity that employs M&S artifacts in the formative assessment of each student. Teachers asks questions of individual student about knowledge that was covered and skills that were practiced. This activity is more appropriate near the end of a unit of instruction. A student can answer questions and demonstrate knowledge and skills using M&S. *M&S individual question session* can be used to achieve many Bloom's levels, depending upon the teacher's questions and the student's knowledge and skills.

M&S group question session is an activity that uses M&S artifacts as a formative evaluation of the collaborative efforts of a group of students. The teacher asks questions to groups of students about knowledge that was explained and practiced. Students within the group communicate to generate a consensus response. Students answer questions to demonstrate their knowledge and collaborative skills using M&S artifacts. *M&S question session* supports many Bloom levels. Place this activity near the end of a lesson.

M&S home activity involves using M&S artifacts for teacher-assigned tasks completed by students at home. It can often serve as an assessment. Tasks focused on previous lessons help reinforce concepts using M&S artifacts and deepen knowledge. *M&S home activity* can also be used in a flip class format as a mechanism for preparing students for an upcoming lesson by covering prerequisite knowledge and skills, or by providing a refresher based on the previous instruction.

M&S performance assessment is an activity that uses M&S artifacts to assess learners' achievements of learning objectives, business objectives, and M&S objectives. This is a summative assessment, usually covering multiple units of instructions.

M&S *individual project* is an activity in which student must propose solutions to real world problems and conducts necessary analysis and evaluation to support them using M&S. To complete the project, student will be required to demonstrate knowledge of port management using M&S skills across multiple levels of Bloom's taxonomy. Problems may be proposed by a teacher or by a student. The time to complete the project will be determined by teacher and will likely span multiple units of instruction. This activity differs from *M&S home activity* because it has a larger scope, encompassing multiple lessons and serves as a summative evaluation.

M&S group project is a version of *M&S individual project* in which a group of students work together on a project. We recommend using *M&S group projects* before *M&S individual project* to enable students to collaboratively learn the tools, concepts, and the process of developing M&S-based solutions.

Selection and sequencing of instructional activities

Selection and sequencing of instructional activities aims to ensure a proper coverage of skills and knowledge at the desirable Bloom levels. It should also promote both durable and efficient learning by considering both short-term and long-term goals (Rawson & Dunlosky, 2011). While future research is necessary to increase our understanding of how the brain and cognition changes as a function of learning (Ansari, De Smedt, & Grabner, 2012), e.g., in problem solving (Stevens, Galloway, & Berka, 2006) during M&S activities, the example guidelines are specified based on information gathered in the previous steps of IDM, principles of effective instruction (Munro & Clark, 2013), and cognitive load theory framework (Wong, Leahy, Marcus, & Sweller, 2012). These guidelines can serve as an initial idea demanding an empirical research necessary to establish base line dependencies between factors. They should be used to develop more precise method for selecting and sequencing instructional M&S activities. Because at this point of research we do not have data supporting selection and sequencing, the guidelines have qualitative, informative character.

In order to select M&S activities, one should establish a time budget of all activities, including total assumed time of weekly student effort. This time includes the total time for in-class activates. It is assumed that in-class M&S activates range between 10 and 30 minutes to keep learners engaged and motivated. The goal is to sustain the cognitive activity at a sufficiently high level to enable effective learning, but not too high to avoid cognitive overload. Assuming traditional weekly format found at universities, the process of selecting M&S activities should consider several factors affecting cognitive load:

- Total assumed time of weekly student effort (step 1)
- Total time weekly in class meetings (step 1)
- Initial Bloom's level (step 3)
- Desirable final Boom's level (steps 2 and 4)
- M&S coverage (step 4)
- Assumed time required for each single activity (step 5)

If the M&S environment limits a particular knowledge or skill, then other activities must be incorporated to complement M&S activities. While traditional lecture-oriented instructions are not well equipped to stimulate higher Bloom's levels, M&S activities arguably can improve learning at higher Bloom's level. With better representation of the domain knowledge and skills using M&S artifacts, we can expect the cognitive load during learning to be higher because more dependencies can be learned and practiced at ever higher Bloom's levels.

Instructional designers should estimate how many M&S artifacts, and how many dependencies between them can be effectively learnt within a given time. For long activities with a large number of M&S artifacts, the information may exceed working memory limitations and make learning ineffective. If more time is required to achieve a higher Bloom level it is better to break a single lesson into two weeks and use M&S activities that enable transitions between levels. This is where new research is needed to facilitate quantitative estimations. Taking into consideration these limitations, in Figure 9 we show an example of using generically sequenced M&S activities to assemble a unit of instructions.

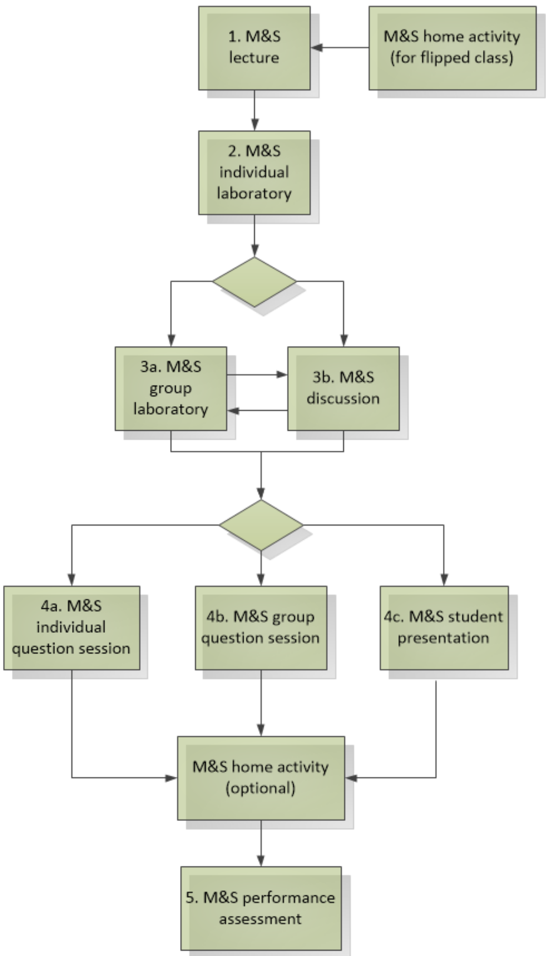

Figure 9. Generically sequenced M&S activities to assemble a unit of instructions

When introducing new knowledge within a unit of instruction, we recommend starting with *M&S lecture* as the initial activity. *M&S lecture* aligns well with low Bloom's level to facilitate learners' remembering and understanding of the topic, facilitating student learning of vocabulary, definitions, visual representation, and a basic understanding of system behavior. Next, it is important to practice the knowledge by applying it to move the knowledge from working memory to long-term memory. *M&S individual laboratory* can serve this purpose. Based on schema theory (Wong et al., 2012) we recommend next the use of the *M&S group laboratory* or *M&S discussion* where students can 'borrow knowledge' from other's long-term memory through discussion, collaboration, and competition. These activities when properly moderated by a teacher should facilitate situations where problem-solving skills are acquired. If highly collaborative problem-solving skills are desirable, we recommend stacking these activities one after another. The next activity is selected from a set of three M&S activities: *M&S individual question session*, *M&S group question session*, or *M&S presentation.* They provide opportunities to generate more feedback from students about their progress through instructions, providing formative assessments.

Teachers may prescribe *M&S home activity,* to allow practice at home using M&S as directed in their assignments. Optional *M&S home activity* can be also used when prerequisite material must be acquired by students before class. This is commonly called a flip class format. In this format teacher can provide simulation models and video tutorials to the class, so students become familiar with a subject. This way time of *M&S lecture* and *M&S individual laboratory* can be minimized, leaving more time for collaborative activities. After all the learning activities are completed *M&S performance assessment* is conducted to evaluate results of the students completing multiple units of instruction. One can combine traditional assessment methods with the use of M&S artifacts.

3.2.6. Developing content of activities

Based on the selected M&S activities and their sequence, instructional designers should be able to develop all instructional M&S artifacts and prepare formats and mechanism for reporting results of for those M&S artifacts developed by students. For instance, emails or cloud storage for managing M&S artifacts within learning management system can be used. The SEELS interface allows for very fast and intuitive development of highly configurable models. No programming is required to develop instructional material in SEELS. Models are defined using GIS maps and semi-transparent polygons representing infrastructure. SEELS allows the saving of both the simulation model and output data within a single file; this makes it easy to communicate most of the M&S artifacts except for processes which are external to the main graphical user interface.

3.2.7. Evaluation of instructions

Evaluation is used to continuously improve instructions. Many methods can be used to conduct evaluation of instructions (Cohen, Manion, & Morrison, 2013). Evaluation of instructions may, for instance, include objective evaluation of the students' learning outcomes, subjective evaluation based on learners' feedback, and subjective feedback from instructional designers who applied IDM.

Moreover, evaluation of factors related to the instructions themselves should be considered. The length of M&S activity is an important factor that should be evaluated. The evaluation should also assess feasibility of advancing to the desired Bloom level based on M&S coverage within the M&S activity and the total weekly class time. Automatic recording of total usage time of SEELS by students, and more detailed information about student interaction with the M&S environment could offer valuable insights for improving the curriculum and specific learning activities. For instance, it could provide insight about how much practice is enough to reach a particular Bloom level, about including a single learning activity versus relearning activities, and about common learning strategies used by students (Rawson & Dunlosky, 2011). This brief discussion covering evaluation of M&S based instructions is not limited deserving of a separate paper.

4. FUTURE WORK

This paper described initial efforts to create M&S based IDM. A case study demonstrating the use of proposed IDM to design and develop a sample lesson, including M&S artifacts, is planned as an extension of this work in the near future.

The future work should include continuous improvements related to selection and sequencing based on evaluation of instructions. Refinements can initially be made by adopting the "learning by doing" approach, i.e., using IDM to develop more instructions for port management and then evaluating them. Our insights could be considered for applicability across different domains and different M&S environments as a basis to improve and generalize IDM. Guidelines for selecting appropriate M&S environments based on more tangible criteria in the context of educational purposes is yet another topic that needs more research.

The cognitive load during knowledge and skills acquisition based on using M&S activities is difficult to measure using available methodologies thus limiting the use of objective criteria for selecting instructional activities. More research is needed in estimating cognitive load during M&S activities. Evaluation methods for M&S-based instructions are still in their infancy. Future work should find a way to devise more precise research methods at the intersection of neuro-education (Ansari et al., 2012) and M&S. The improvement of IDMs would be facilitated through more synergy between academic programs specific to a domain, academic programs that educate future developers of M&S environments, and industry partners that commercialize them.

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