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COLLABORATIVE NETWORKS OF KNOWLEDGE

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Abstract

Numerous learning systems have emerged over the past two decades promising novel approaches to improve education and training. However, they use a learning process based on exposure to information and practice, which does not guarantee the internalization of the concepts and changes in behavior required to improve education and training. This paper proposes a learning process that aims to address this concern. It consists of five steps: modeling the learner, motivating, guiding, assessing, and attesting the learner. We present each of these steps and discuss how leveraging innovative knowledge structures from network science and existing and emerging technology and AI can support the proposed learning process in a learning system that engages learners in their learning journey. Our discussion is supported by a theoretical framework developed based on data on student learning and on student and faculty experiences with two learning systems where we piloted steps of the proposed learning process. Each learning system has endured the scrutiny of student and faculty usage over several years and their feedback has shaped our goals and expectations.

Keywords: *Network of knowledge, individual learning pathways, personalized education, micro-learning.*

1. Introduction and motivation

Learning is shaped by how a person receives, internalizes, and then uses information (Huitt & Hummel, 2003). Learners' experiences, biases, environments, cognition, as well as other factors, impact the way they engage in the learning process. Traditional education systems are structured to push knowledge at students through compulsory or comprehensive university curricula, not necessarily designed to ensure such content has relevance to each student's current needs and competencies, but instead communicating a payoff after a multi-year process, demotivating the learners. Instead, learning should be seen as productive and attractive in its ability to meet each student's current needs and interests. Thus, the design of a personalized Learning and Development System (LDS) must support the recognition of relevant learning traits from each learner to support the necessary customization of personalized learning strategies.

We propose and exemplify the creation of a personalized Learning and Development System (LDS) that must adapt learning content with appropriate instructional design principles and address the following about each learner: 1) learner competency, to address personal cognitive load and working memory limitations; 2) required structuring and organization of learning activities; and 3) personal agency within a collaborative learning model. We focus on how information technology enhances the learning process as a tailored experience that includes modeling the learner, guiding the learner, motivating the learner, assessing the learner, and attesting the learner. Specifically, we discuss how a network of knowledge captures a nonlinear foundational construct supporting these learning process activities, so that the LDS creates learning-centered pathways through the network to support a personalized learning experience.

To understand how network science can support the learning process, we leverage motivating and guiding the learner through self-directed and self-paced learning opportunities in an educational environment conducive to meeting the learners' needs through facilitating a participatory environment. Such efforts push the limits of the current educational systems, tools, and a learning system's capabilities. Our contribution includes an examination of a dynamic network of knowledge as a foundational construct

to create a personalized educational experience that meets the set learning outcomes of each learner individually.

2. Theoretical grounding

In this section, we synthesize the learning science and network science components addressing the extrinsic and intrinsic motivation of learners.

2.1. Learning science

Learning occurs when a person processes, organizes, and connects new information to preexisting ideas to create new meaning (Bransford et al., 2000). The learner's ability to receive, reflect, and internalize information, within the limitations of working and long-term memory, is an important consideration when designing an LDS. Learning requires effort, and if working memory is overloaded, a person will be unable to continue to receive new information, thus degrading the learning process (Cook & McDonald, 2008). Learning content design–the design of activities, their structure, and the scaffolding and segmentation of content–is an important aspect of managing cognitive load. Technology can support a design that presents learners with the necessary expert guidance utilizing instruction and micro-modules, also known as chunks, with opportunities for checks for understanding. Self-contained micro-modules allow the user to pause the learning process in a natural way, reducing strain on the learner and restoring a learner's capacity for taking in new information. Additionally, as a learner progresses through assessment activities, the incorporation of adaptive learning tools can provide learners with critical feedback tailored to their specific challenges.

Chang et al. present a model for how a learning system can automatically identify a learner's working memory capacity by analyzing the learner's behavior (Chang et al., 2015). Through the monitoring of students' activity log information within a learning system, mechanisms are introduced. Thus, a personalized LDS would capture learning data, update learner characteristics, and adapt the recommendations presented to the learner from a repository of resources which should naturally and easily be curatable for the learner. So, the LDS filters and suggests content that is most relevant to each learner, mitigating the risk of overwhelming the learner while also supporting the curator of content (Reith & Dever, 2021). Additionally, learner agency within the personalized LDS supports the understanding, ability, and opportunity for the learner to take an active role in the learning process, thus the LDS design empowers the learner while mitigating the excessive demand for working memory. Bartlett introduced the idea of learning schemas as a necessary component of cognitivist learning theory which is the basis for this research (Gholson & Craig, 2006). Therefore, the formation of mental representations of interconnected content is important for learners to establish connections between existing knowledge and new complex knowledge supporting improved retention and storage in long-term memory (Van Merriënboer & Sweller, 2010).

2.2. Collaborative environments: Network of knowledge

In creating a student-centered learning environment within higher education, we seek to facilitate learner knowledge creation through experience rather than just transmission from the subject matter expert to the learner. A networked environment can support experiential learning, cognitive learning, participatory learning, case studies, discussions, and other problem-solving methods leveraging pre-existing resources available on the Internet to populate learning pathways (Feldman et al., 2000). Learners are guided through this networked environment as self-directed and self-paced users, supported by asynchronous or synchronous engagements.

The Network of Knowledge is an environment to which subject matter experts (SME) can collaboratively contribute and tag content based on their area of expertise, and then connect it based on pre-requisites or dependency in a non-linear way (Cleven, 2018). Existing prototypes provide a real-time adaptive micro-learning method for enhanced and personalized education (Gera et al., 2019). A Network Science approach for learning focuses students through networked learning pathways recommendations in the presence of information overload. Self-paced learning has been practiced and empirically analyzed using intentional and meaningful networked content and activities through a network approach (Gera et al., 2019). An interconnected model of education brings an interconnected (non-linear) view of knowledge and its users. That is, we also model the learning support as the users' social network comprised of content creators, instructors, instructional support staff, stakeholders, sponsors, and learners.

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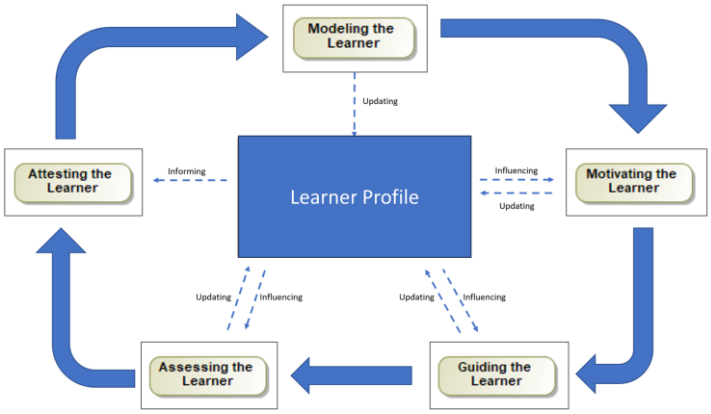
3. Context of the research

We now introduce our model for the personalized learning process proposed in a networked environment inspired by existing models. Figure 1 depicts the learning components into the learning cycle, whose information is retrieved into a learner profile and used to personalize learning.

Figure 1. The Learning Cycle shows activities associated with learning and their interaction with the learner profile.



The learner profile is automatically built on data collected from the learner, such as employment, education, interest, personality, preferences, and accessibility of resources. In formal courses, instructors attempt to elicit some details through student introductions, discussions, and engagement over time and use the data to scaffold material as they teach, a difficult practice due to large class sizes and diversity. An LDS can easily collect and use the data to personalize the learning experience and content. This may manifest in at least three ways. First, some learners may start at an advanced point in the curriculum based on their existing knowledge. Second, teaching examples and analogies may be customized to align with familiar experiences. Finally, understanding the learner's attitude toward a topic may help the LDS choose an appropriate teaching strategy. These learner profile categories can be leveraged in the five components displayed around it in Figure 1, and detailed next.

Modeling the learner has often been associated with understanding prior knowledge. Formal pre-tests and baseline assessments as well as queries on background experiences are common as instructors interact with learners including related experiences and attitudes. This knowledge can be used by the instructor to adapt examples to build off this information. The learner profile is a set of goals, a set of competencies, and a set of constraints. Chief among these competencies is the learning competency that models the proficiency of the learner to acquire competency. Crafting adaptable micro-modules to personalize learning as well as cultivating them into a personalized pathway requires background information on the learner stored in a learner profile. The ubiquity of data opens the opportunity to shape customized learning experiences by tailoring the curriculum making it efficient compared to commonly observed approaches in today's education, such as one-size-fits-all or differentiated by group level.

Motivating the learner includes motivation to start learning a topic and motivation to endure the process to completion. The former may involve such intrinsic motivators as a need to address an immediate issue, seek out a better quality of life, or the pure joy of learning and satisfying curiosity. The latter may involve extrinsic motivators such as grades or demonstration of competency, improved by personalization of learning and supporting learner's meta-cognition. First, to support dual encoding of information through exposure to diverse modalities of interacting with the content, we envision leveraging the learner profile's tags to match appropriate content from the network of knowledge. This supports each learner individually by providing content that motivates each learner based on the tags in the learner profile. Second, to support meta-cognition, the LDS provides immediate and specific feedback to each user to have the opportunity to improve self-learning based on the reporting that the environment captures.

Guiding the learner is the process of presenting and sequencing learning materials, achieved by using best practices such as spaced repetition, elaboration, visuals, concrete examples, and concept maps. For the directed learners, we guide them individually through learning paths throughout the network of knowledge, by ranked ordering choices of content that meet the same learning outcomes, offering scenic routes, thus empowering the learner in selecting the depth and breadth for topics. As the motivation for learning changes for more mature learners, to progress towards exploratory learning, the LDS provides choices of micro-modules, driven by keyword matching to the learner's profile based on an updated list of

keywords from the learned content, based on social networks of the learners (Andriulli et al., 2019).

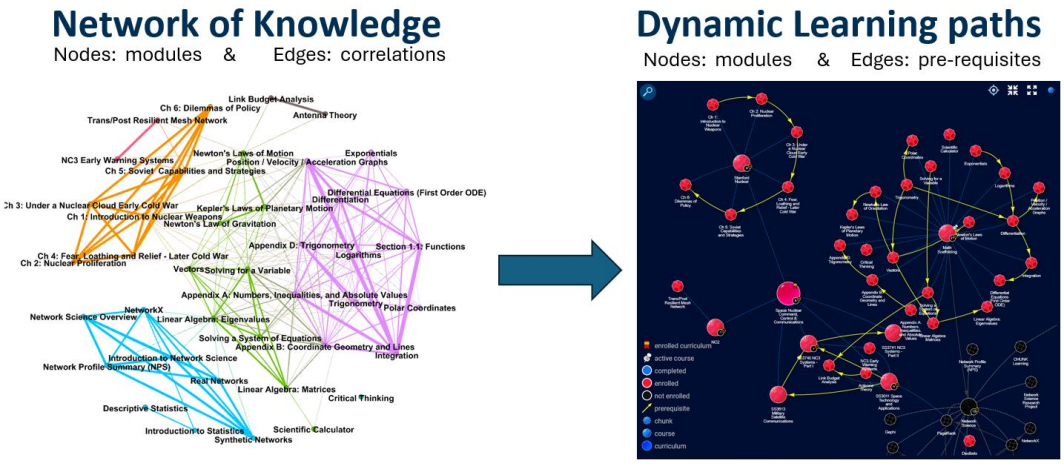
Assessing the learner often involves measuring competency, such as adaptive knowledge, skill, ability, behaviors, and characteristics. Personalized learning depends on granular data for successful agile scaffolding from micro-modules, determining the learner's current state of knowledge and gaps to meet the goals. Such assessments not only provide feedback to a learner's end state at the completion of a learning, but the learner's starting state when engaging in the next activity guaranteeing relevant learning. As such, student-centered assessments that establish evidence about the learning process and validate the competencies achieved, such as formative assessments, support understanding of learning at different instances continuously monitoring the ability to relate new information to previously acquired principles. Additionally, they provide critical feedback to the learner and to the LDS on the effectiveness of the learning pathway and help uncover weaknesses or gaps in understanding.

Attesting the learner involves witnessing evidence of competency and certifying the learner to others. Whether it manifests as a degree, certificate, testimonial, reference, or digital badge, a record of competency helps the community efficiently understand a person's proficiency in a topic. The LDS tracks and provides immediate attestation of the learner's progress to inform his decisions, while the learner progresses through the learning path. Consequently, the educational ecosystem must be dynamic, flexible, and a rich cognitive environment supported by adaptable micro-modules based on the LDS' reporting.

4. Experimentation

We piloted this methodology in entry, survey-courses and advanced courses in statistics, modeling and simulation, advance math courses at the Naval Postgraduate School starting in 2018. We created a network of knowledge for these courses, with students able to get personalized content based on the information in their learner profile, with additional options to suggested content. A visual of the network of knowledge is depicted on the left of Figure 2 where nodes represent content modules, and the edges capture similarity based on the tags associated with the content (thicker edges represent more tags in common). The right picture of Figure 2 shows learning paths through the network of knowledge, as displayed to the learners.

Figure 2. A Learning Path is displayed on the right in red, based on the Network of Knowledge environment.



We assessed the pilots using data on prior knowledge, cognitive competencies, perception of the learning system and instructors, and cognitive processes using pre-, and post-course questionnaires, augmented with focus groups. We consistently found that students in all level courses valued the flexibility in the choice of content in LDS environments. While all students responded they preferred some interaction with the instructor, students in introductory-level courses were more likely to state the choice and visualization of the learning paths through the network of knowledge that supported their learning by preparing them to engage in meaningful learning through interactions with their instructor. For advanced, complex topics, only about half of the students preferred the piloted LDS learning environments. The recommendation asks for a larger amount and variety of content choices to increase the students' engagement and better support their learning. The assessment of the pilots points to the exciting possibilities in using an LDS system and demonstrates the need to continue to expand our understanding of the art of the possible that ensures students are exposed to relevant and meaningful learning.

5. Conclusions

In this paper, we ask whether personalized and individualized learning can occur effectively and efficiently in a learning environment that benefits from advances in technology. We introduce an environment where learners are guided by personalized learning paths through a network of knowledge composed of interchangeable content, provided by different authors and in multiple modalities of engagement to support dual encoding. Learning in a digital age of abundant content enables opportunities for each learner to make personal choices based on available content alternatives. We present the learning science motivation of why this is needed and introduces our vision of a network science approach to personalized education provided by learning paths of micro-modules from a network of knowledge.

We identify that recommendations for the learning paths can be personalized based on the learner's profile, placing the learner at learning-appropriate location in the Network of Knowledge, and choosing between the learning paths based on each learner's interest. We conclude with an experiment testing such a personalized LDS prototype, alluding to the exciting possibilities that the approach brings. This work presents the vision and is an open call to academics and practitioners to join in the effort to fill in gaps, push the frontier, test what & where works, continuously improve such an educational system and find valuable solutions.

Future explorations should leverage the ability of Artificial Intelligence (AI) to leverage emerging technologies in education design to support both the network curators and learners, since knowledge identification, curation, and uploading is time-consuming.

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