CHUNK: Curated Heuristic Using a Network of Knowledge

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***Abstract*—What is the potential of a 21st century learning environment that mirrors the capabilities of personalized Apps? In contrast to the standard linear or tree-like educational system of sequential lectures or chapters, we propose a real-time, modular, adaptive teaching-learning environment for enhanced and personalized education, called the Curated Heuristic Using a Network of Knowledge (CHUNK) Learning concept. The CHUNK Learning model breaks away from the predictable pattern of traditional education models and provides content delivery that adapts to the capabilities, learning styles, and approaches to problem-solving of every learner. With CHUNK Learning, students are empowered by a student-centered teaching-learning system whose purpose is to make learning engaged, flexible, and respectful of the students' time. Much like a computer game approach, CHUNK Learning system maintains an on-line learner profile for each user, which guides the learner through a Network of Knowledge composed of lesson materials joined together by prerequisite relationships and common attributes based on competency or skill levels. Our vision also includes a mix of different delivery methods, to include demos, videos, interactive applications, TED talks, webinars, programming languages (personalized to the skill of the learner), and data manipulations, all delivered through a combination of online and traditional experiences.**

Keywords*—*CHUNK Learning; network of knowledge; personalized learning; individualized education; networks and education.

I. INTRODUCTION

Traditional education places all students through the same topics, at the same time, at the same pace, generally teaching to the average student. However, such a system fails to provide every student the appropriate opportunity to learn and engage, leaving some learners struggling, while failing to challenge others. A strength in student-centered learning, as opposed to traditional education, is the opportunity for independence and autonomy that enhances different skills, abilities, and interests learners might have. Unlike most established sciences, new research fields such as Network Science (an emerging field overseeing traditional computer science, operations research, sociology, and other fields) hint at non-traditional methods of education that serve as a starting point for the current effort.

The contrast between our views on the potential of 21st century education and the current educational status quo generates ideas which we believe can improve effectiveness of educational programs through enhanced retention, transfer ability and critical thinking linked to learner-centered education. We introduce a vision for an adaptive teaching, flexible learning, and technology-enhanced student-centered education strategy for the 21st century learner that operates in the big data environment [1]–[3]. We describe our view on how different teaching and learning tools can be joined into a web/network of knowledge that will individualize learning and leave a persistent impact on the learner's career. We introduce our unique structure and vision for catering to the needs, motivations, and supply of learners with a system that:

- **Offers** intense, short, and focused educational modules.
- **Stimulates** interest and relevance of topics.
- **Integrates** new information with learner's pre-existing knowledge.
- **Provides** personalized and individualized education.

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- **Optimizes** content and methodology delivery to meet the needs of each learner.

The structure of the paper is as follows. We present related work in Section II followed by a short overview vision of what the system is becoming in Section III. We then introduce the CHUNK Learning framework in Section IV followed by the science behind CHUNK Learning in Section V. We present the Network of Knowledge and its components in Sections VI and VII, respectively. Furthermore, we discuss and provide an example of how CHUNK Learning is individualized and personalized, in Sections VIII and IX. We conclude with further direction, in Section X.

II. Related Work

In the early 90's, education slowly started to incorporate digital resources and use of Internet in the classrooms. By 1999, 80 percent of the schools used these resources in some form [4]. In the same year, studies of the Internet surfaced and network science research started to bloom [5], [6]. Yet, to this day, we still use the Internet and digital resources primarily as a resource for information or to host distance learning and Massive Open Online Courses (MOOCs). Below, we expand on the richer use of pulling educational information to personalize educational content and to position the learner the way Amazon, Netflix and social media do.

Educational content is generally organized in a hierarchical structure following a textbook or a collection of books. Students enroll in a curriculum that consists of several courses. Each course has themes organized into chapters, and each chapter consists of several sections. In general, the smallest level of educational material relevant for learning is a section, whereas the smallest level a student can choose from is at the course level. Our vision for CHUNK Learning is to consider the data in educational content at a more granular level, at the tier of topics, where a section could be comprised of one or several topics, possibly captured on transcripts by micro-credits. Moreover, we consider that, based on design cognition, visualizing the structured representation of concepts and the relations between them as a map allows the learner to generate a deeper, longer lasting learning [7]. Concept mapping allows students to learn in a more meaningful way by elevating their previous experiences and knowledge and relating them to the new concepts for a more complex, longer lasting, more effecting learning [8].

Information theory shows that learners are limited by the amount of information one can receive, process, and remember at the time [9]. Techniques such as "several stimulus dimensions, recording, and various mnemonic devices" along with breaking down the information supports the learning environment. One of these techniques is to present the information in smaller and shorter and interconnected chunks that has been already used for both traditional [10] and for e-learning [11]. A 2014 large scale empirical study by Guo, Kim and Rubin found that shorter videos tend to be more impactful for the students' learning experience than longer videos [12].

A step forward from traditional education is web-based education or e-learning [13]–[16]. Particularly, e-learning received more attention in the form of MOOCs [17], [18]. While the digitization of the lectures gives students freedom in interacting with the content whenever they want, all the students are still exposed to the exact same information, presented in a single way, at a single pace.

Recent studies indicate that e-learning efficiency can be dramatically improved if personal prerequisites, skills, and individual learning preferences of students are taken into account [19]–[21], often referred to as *personalized learning*. "Personalized learning refers to instruction in which the pace of learning and the instructional approach are optimized for the needs of each learner. Learning objectives, instructional approaches, and instructional content (and its sequencing) may all vary based on learner needs. In addition, learning activities are meaningful and relevant to learners, driven by their interests, and often self-initiated." [22].

A step further from personalized education is the adaptive personalized approach that requires both detailed profiling of the student's personal learning preferences, an extraordinary collection and annotation of educational material, and updating the profile based on the annotation of educational materials [23], [24]. The latter is necessary in order to identify educational material best fitting the student's profile. Network science can provide important tools that help to achieve these goals, as we explore in this paper.

III. On Becoming a System

We envision a network science approach serving as the foundation for real-time personalized adaptive learning. All curated educational content contained within the content management system is presented as a Network of Knowledge, that learners can navigate based on prerequisites and correlations of topics. Building upon this foundation, the learning management system must contain a personalized and individualized recommender system which matches learners' needs (as stored in student profiles) with educational content (stored in the repository of CHUNKs), and presents each learner with a personalized network as part of the Network of Knowledge comprised of all the existing CHUNKs. Lastly, we envision an adaptive learning environment where student profile data and educational content are continuously updated, based on observed patterns of learners supported by artificial intelligence.

IV. Curated Heuristic Using a Network of Knowledge

The proposed CHUNK Learning is a real-time and Adaptive teaching-learning method for enhanced and personalized education. It provides a Curated way of moving through a Network of Knowledge composed of reusable learning objects joined together by common attributes (i.e., tagged

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with competency or skill levels), rather than following the standard linear or tree-like system of lectures or chapters. CHUNK Learning thus enables the learner to Heuristically discover or learn based on personal background and interests, which we believe will not only enhance the learner's talents, but will make them a more valuable resource. This system is live at [25].

How do we achieve CHUNK Learning? Our learner's interests determine his/her own learning path through the Network of Knowledge with individualized learning outcomes. Each student benefits differently from the learning experience, based on his/her skills and desires. Simultaneously, the Network of Knowledge builds on the experiences of the students covertly guiding learners through the educational materials, much like Amazon provides recommendations for buyers. We achieve this by moving away from interdisciplinary teaching that transfers methods from one discipline to another, opting instead for a trans-disciplinary teaching approach that crosses the boundaries of many disciplines using a diverse choice of teaching tools and software.

V. The Science behind CHUNK Learning: A Motivational Framework

In determining how best to create a platform to support both educators and learners, CHUNK Learning focuses on addressing how to positively affect educational engagement as well as stimulate enthusiasm for self-directed lifelong learning. Research supports the need for educators to effectively connect with learners by addressing learner motivation. Pink and Brophy identified the importance of providing relevance and utility of content as students are motivated when they understand why they are being asked to learn certain material [26], [27]. It is paramount that the learning platform focuses on providing learners the answers to "why should I care about this topic." Additionally, adult learners are more likely to engage in learning when topics have intrinsic value and demonstrate importance within the context of their lives [28]. Providing context for "how will I use this knowledge in my life" ensures learners connect the overall purpose and goals of instruction.

Personalized learning software respects the reality that all learners are unique and, in order to maintain proper motivation, it is necessary to support their different learning styles and timelines. Utilizing key motivational strategies to include a variety of content delivery methods and styles helps ensure learners generate and maintain a positive attitude towards learning [29]. Additionally, recognizing that even the most motivated, self-directed learners may experience challenges in the pursuit of education, it is necessary to employ strategies that promote learners' control over the delivery of short and intense modules. Respecting learners' time and empowering learning-oriented learners to engage in self-directed study establishes an inclusive invitation to education [28].

CHUNK presents learners materials in a variety of formats supporting multiple pedagogies. This orientation emphasizes: the use of multiple mental and pedagogical representations; the promotion of multiple alternative systems of linkage among knowledge elements; the promotion of schema assembly (as opposed to the retrieval of prepackaged schemas); the centrality of "cases of application" as a vehicle for engendering functional conceptual understanding; and the need for participatory learning, tutorial guidance, and adjunct support for aiding the management of complexity. This approach is geared towards an active construction of new knowledge and critical thinking skills, which is especially learning-enhancing for adult learners who bring a large array of previous experiences and knowledge to their educational journey [30]. Similarities in prior experiences or interests among learners can generate new paths of learning in a network-of-knowledge based system, further deviating from the linear path of the traditional education. We envision an array of assessments of the CHUNK-generated learning and experiences, relative to the traditional, linear educational system, with the paramount goal of enhancing learning outcomes and guiding the continuous shaping of the CHUNK Learning environment.

VI. Educational Material as a Network of Knowledge

This research uses a network science [31] approach to represent educational content that facilitate learning as a map of aggregated materials. This collection of educational materials and the curration that holds it together forms a *Network of Knowledge* formally defined by Cleven as:

> *A **Network of Knowledge** is the representation of educational material as a (multilayer) network, in which educational content builds nodes that are linked by common attributes in several categories, such as content, prerequisites, instructors, level, etc. Each category of attributes links the nodes in one layer, which provides an ability to filter the entire collection of material with different perspectives.* [32]

We establish the network using metadata attached to the educational material. We envision the backbone of the network as a keyword ontology describing relationships between the content the learners frequently access. However, also included would be other relationships such as content authors, prerequisites, media types, and learning methods. A visualization of the Network of Knowledge thus established is depicted in Fig. 1.

VII. Why-How-Methodology-Assessment

Our work establishes a baseline template that all CHUNK Learning modules follow, displayed in Fig. 2. This format facilitates learning as an adaptation of Simon's "Why-What-How" [33] format. For example, in introductory courses in science, the common practice is to provide a motivation for the concept-to-be-introduced, with the message that the learner will eventually be using the learned concepts. CHUNK Learning's "Why-How-Methodology-Assessment"

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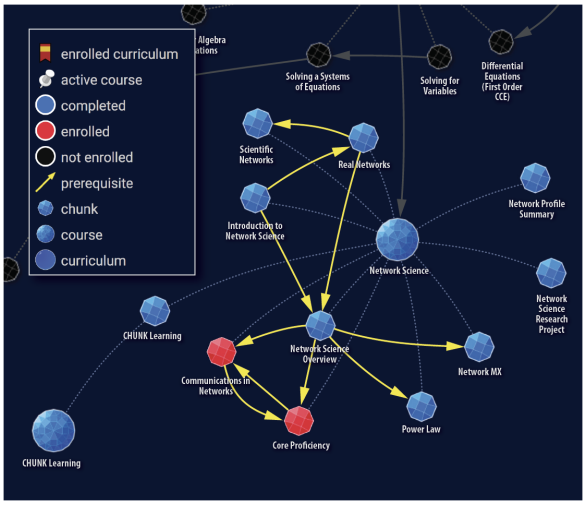

Fig. 1. CHUNK Network of Knowledge.

reverses this process. It is top-down teaching by anchoring the concept-to-be-introduced to each learner's knowledge before introducing the methodology for the new concept. It shows each learner how the content is used in that learner's specific field of study, so that it has meaning and context to the learner, before the learner even engages with the new content. This is accomplished by having multiple choices for each of the category in "Why", "How", "Methodology", and "Assessment", in order to optimize the matching of the content to each user. Throughout the paper, "user" and "learner" are used interchangeably.

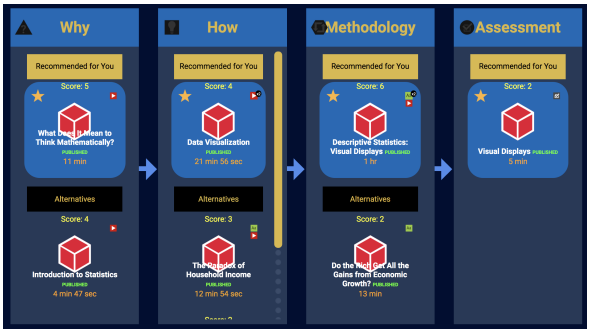

Fig. 2. Why-How-Methodology-Assessment Format.

1) **"Why": Tantalizing the Learner**. Learners open a "Why" CHUNKlet to reveal an enticing one-of-its-kind educational trailer. The goal of CHUNK Learning is to make the student eager to learn, so all CHUNKs begin with a demonstration on **why** learning a particular topic is important. Much like a movie trailer attracts moviegoers to a movie, the "Why" CHUNKlet attracts an exploratory learner to the CHUNK Learning module, answering the following questions:
   - Why is the topic relevant?
   - Why should students learn the topic?
2) **"How": Applications, Real and Relevant** Learners dive into the "How" CHUNKlet to uncover real and relevant applications. Here, students discover the answer to the often-asked question, "When will I ever use this in real life?" We also seek to answer the following questions:
   - How is the topic applied in practice?
   - How does the learner validate what he/she already knows?
   - How are the learning outcomes tested?
   - How is new information, anchored to the learner's interests, incorporated into the module?
   - How can the learner apply the acquired skill/knowledge?
3) **Methodology: A Variety of Delivery Methods** Instructors carefully curate the "Methodology" CHUNKlets, guiding students though a variety of personalized course materials and delivery methods, including MOOCs and Creative Commons Licensed resources, as well as instructor-created content. For interactive modules, we envision that instructors will follow the "I do it, We do it, You do it" model. The "Methodology" CHUNKlets' main focus should be on answering the following questions:
   - What new information and skills will the module deliver?
   - What activities will the learner be required to perform?
   - What learning outcomes will the learner acquire?
   - What different methodologies could be used to engage with this new knowledge?
4) **Assessment: Competency Based** Learners can jump into the "Assessment" CHUNKlet at any point in order to test their knowledge on any given topic. Assessments are available for every CHUNK. Opportunities for remedial learning are always present. Successful completion results in a CHUNK competency credit.
   - What is the competency-based framework, designed around learning objectives, needed for each CHUNK?
   - How should remediation be tested?
   - How should the post-test differ from the pre-test?

We encourage instructors to complement this basic structure with innovative methods of incorporating information and engaging the learners.

VIII. Individualized System

Due to their various academic and professional backgrounds, learners have unique gaps between current knowledge and required predefined course knowledge standards. Additionally, individuals have different skills, preferred learning modes, and motivation to learn. This challenges educators to expand the one-size-fits-all education method to effectively engage with learners. CHUNK Learning provides an interactive learning system that is able to identify each learner's unique knowledge and skill gaps and then fills those

Category	Examples
Application topics	Social networks, Cyber, Bitcoin, Biology, Economy, Neuroscience, Internet, etc.
Programming Skills	Fortran, C, C++, Python, R, JMP, Matlab
Education	GED, A.A., A.S., B.A., B.S., M.A., M.S., Ph.D
Training	untrained, trained, need practice, refresher

TABLE I. Sample tags used in the profile set up to support individualized experiences

Category	Examples
Occupational Specialty	Educator, engineer, etc.
Professional Experience	Department chair, research team lead, etc.
Interest level	Depth, breadth, familiarity, practice, gist
Goals	Reinforce something learner knows, expand knowledge, get the gist
Preferred learning modes	Videos, PPT, exercises, research papers, simulations, demos

TABLE II. Sample tags used in the profile set up to support personalized experiences

gaps, ensuring the required knowledge outcomes are met based on the student's uniqueness, as exemplified in Table I.

In CHUNK Learning each learner creates a "user profile" tagged with keywords such as the examples from categories in Table I, based on the specific user's background. This profile is used to attract CHUNKlets with matching keywords, to present individualized learning materials. Each learner's profile updates as the learner explores CHUNK Learning. A video introducing users to the profile can be found here.

Similarly, each CHUNKlet in the Network of Knowledge is tagged with keywords, like the examples shown in Table I and more. Once the learners register for particular CHUNKs, the content inside the registered CHUNK gets suggested to users based on the count of keyword matches between the tags of the profile and the ones on the CHUNKlets of the registered CHUNK. The count of keyword matches is displayed above the CHUNKlet, allowing the user to make personal decisions and possibly take a scenic route to complete the CHUNK. The CHUNK Learning's set of tag and categories grows based on users' suggestions. A video of how learners would use this Network of Knowledge can be found here.

In CHUNK Learning, an author builds the necessary CHUNKs within a course to ensure all learning objectives are met at completion of all course's assessments. The CHUNK Learning system provides a pre-test capability for each CHUNK, allowing learners to validate an individual CHUNK by demonstrating competency while bypassing the "why," "how," and "methodology" CHUNKlets, and completing the "assessment" CHUNKlet. Learners then engage with remaining CHUNKs to satisfy the required learning objectives of the course. The result is an interactive system that identifies and satisfies unique gaps of individual learners, respectful of the learner's time and interests.

IX. Personalized System

CHUNK Learning does more than provide a platform for educators to individualize instruction for learners, it allows users to take control of and be responsible for their learning. The CHUNK Learning system also incorporates information from the learner profile based on the categories and examples of Table II.

The matching between these categories captured in the learner profile and the CHUNKlets counts the same way towards the score displayed above each CHUNKlet. The difference is in the type of information it captures in order to offer a personalized presentation of the educational materials, as well as a personalized path through the content. This is supported by system delivering engaging content tailored to users' learning preferences, and relevant to their specific interests and realities of their daily and future lives.

By providing a network-based system, CHUNK Learning is able to facilitate an education environment where learners can see the connections between the topics captured by the CHUNKs and how they fit together, much like a digital visualization of a map of the world. Thus, similarly to navigating using the map, one can navigate the CHUNK Learning network following the arrows that point from the prerequisites of the desired content. As there might be multiple ways to get to a destination CHUNK, this visualization allows the learners to asses the different paths to the desired CHUNK or CHUNKs, producing personalized learning plans decided by students while guided by the content creators. To see an example of this, consider a learner who likes sports and has enrolled in Newton's First Law of Motion CHUNK as a refresher of a previous exposure to the topic. Thus, the CHUNK trailer captured in the "Why" video is presented based on American football motivation. This is followed by an application to the science of Olympics in the "How" CHUNKlet. Once the learner was presented with these concise, rel and relevant educational videos, he/she is engaged in the learning of the new content, the "Methodology" CHUNKlet. In this case, as this is a refresh of a topic, the user is routed to a Distance Learning type of environment to reinforce the topic; otherwise, for a new concept, a classic in class delivery method may be more effective. The CHUNK concludes with the assessment.

Learners' curiosity is ignited as they peruse a wide range of topics, see the connections between them, and determine areas to engage in deep study, utilizing assessments to meet their own learning goals.

X. Conclusions and Further Directions

In the 21st century's fast-pace environment, surrounded by personalized experiences that smart phones offer through apps for shopping, movie watching and so on, education seemingly lags behind in supporting digitally native learners. Traditional education has many recognized shortcomings. It typically presents the same educational content in a linear, same-pace, same method of engagement for all students, with a general goal of teaching to the average student. Traditional education, therefore, produces similarly skilled graduates with the same knowledge. Moreover, traditional

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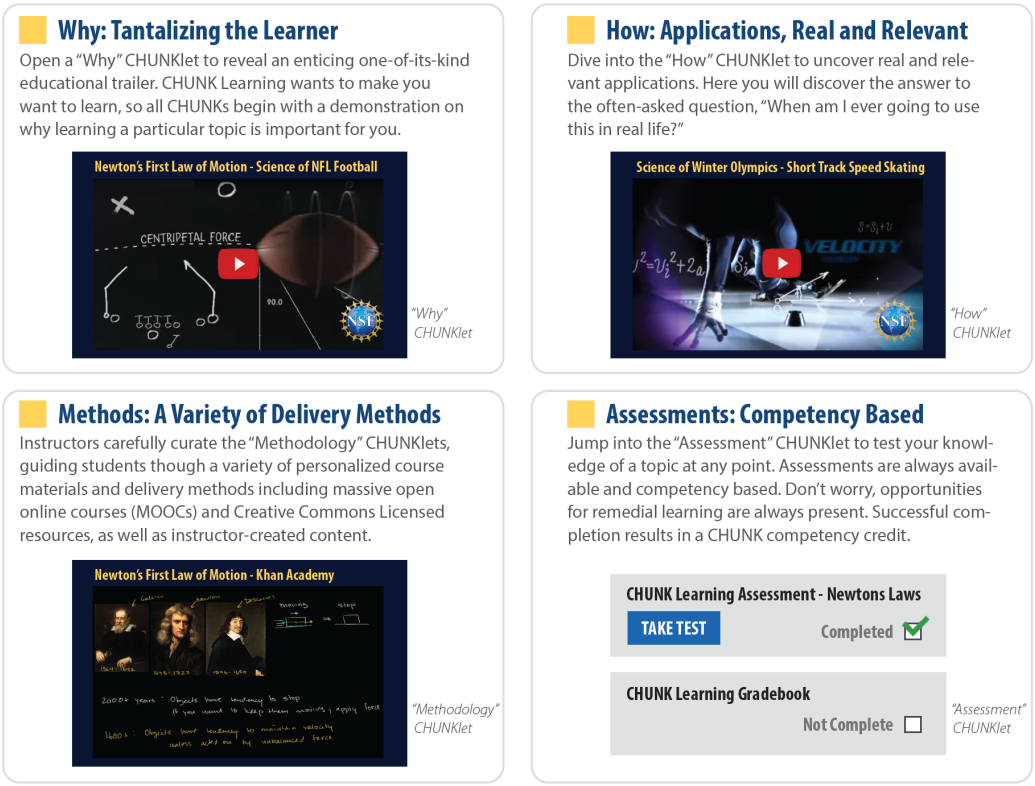

Fig. 3. An example of a personalized CHUNK for an American football fan, reinforcing Newton's First Law of Motion.

education generally fails to enhance the different skills, abilities, and interests of the individual learners. Advances in new research fields, such as Learning Sciences, Artificial Intelligence and Network Science, provide us with hints on how to address shortcomings of traditional education and support our vision for a new, non-traditional system of learning.

In this work, we capitalize on the new research fields and theories to introduce a first step towards a personalized, adaptive learning platform, called CHUNK Learning. CHUNK Learning breaks away from the predictable pattern of traditional education models and provides content delivery that respects the different capabilities, learning styles, and approaches to problem-solving of every learner. Students are empowered by a system that ensures learning is efficient, flexible, and respectful of their time. Intense and short educational modules, broken into smaller bits of information, stimulate interest and applicability of topics through the use of "Why learn this" content. It integrates new information to learner's pre-existing knowledge through a "How do professionals in your field use this" demonstration that is personalized to individual learners' backgrounds to provide valuable context on how learners can use that knowledge in their fields of expertise prior to learning new topics. This allows the anchoring of the new information, supporting meaningful and long term use of the new acquired knowledge.

Supporting our desire of a system that meets the learners where they are, rather than a system where learners depend on standardized instruction from faculty, CHUNK Learning also provides personalized & individualized education. This is based on the learner's best learning style (both at the instructor level and at the content level) along with adaptive content and methodology delivery that are optimized for each learner.

We thus provide an exploratory environment that promotes curiosity and creativity, collaboration and collegiality as we search for meaningful ways to bring together and curate knowledge for generations to come. This vision on the future of learning also demonstrates the art of possibility in teaching and learning leading to new partnerships with industry, government, and academia to support education. It shows the educator's commitment to providing the best in education that speaks to each learner.

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