An Analytical Study of the Design of Flexible Online Curricula to Support Just-in-Time Learning

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***Abstract*—Massive and learner-centered open learning has become a major trend in distance education and industrial training programs. Most learners prefer to start learning at any time and location. In this paper, we propose a pipe model to help design flexible online curricula that optimize the allocation of resources for massive-scale open learning. The notions of a linear course and serialized curriculum are defined and applied to facilitate the implementation of the pipe model. The goal of this study was to support just-in-time online learning.**

***Index Terms*—Massive Open Online Course (MOOC), e-learning, distance education, nanodegree**

I. Introduction

In a school that implements just-in-time learning, learners must be able to start learning at any time and complete their goals in a short timeframe. By contrast, learners in typical degree programs with traditional semester courses often require years to complete their goals. In this paper, we propose a method to support just-in-time online learning that allows learners to complete their goals and establish their skillset in a short timeframe.

A. Definition of Online Curriculum

A curriculum is an academic plan that defines the goal and sequence of learning, content, instructional methods, resources, and evaluation methods [1]. The intended curriculum includes what the teacher expects the students to learn; the achieved curriculum covers the knowledge, skills, and attitudes that the students actually learned and remembered [2]. A curriculum can be defined as a sequence of learning experiences.

A curriculum is often designed for an entire degree program. An online curriculum is designed to facilitate online learning. The completion of an online curriculum results in the attainment of an online degree or certification.

B. Linear Course and Serialized Curriculum

In this paper, a course is defined as linear if it can be offered at any time. At most institutions, a semester course is a course that is offered twice a year. Therefore, a linear course can be offered much more often than a semester course.

A curriculum consists of several courses. If the students are allowed to enroll in only one course at a time in a given curriculum, then that curriculum is referred to as a serialized curriculum.

C. Reality

Because a linear course may start at any time, a linear course offered on Mondays can be offered more than 50 times per year. Regular semester courses are only offered twice per year. Therefore, for a linear course with a class size of 30 students, at least 1500 students can participate in learning each year. A semester course would need to accommodate 750 students per semester to achieve the same head count. In the latter situation, a high demand for instructional resources is expected. We can use a simple model to express the relationship among the key factors:

$$T_R = \frac{K}{CP} \times NT \times CS \tag{1}$$

T_R denotes the total yearly student-course count of an institution. For example, three students enrolled in Course A plus four students enrolled in Course B equal a total student-course count of seven. A greater T_R indicates that an institution enables more students to participate in learning.

We assume that the school is operated for K weeks per year. K can be treated as a constant. NT is the number of instructors. CS denotes the class size (e.g., 30 students per class). CP represents the cyclic period over which the course is offered (e.g., 8 weeks). Suppose that CP_l and CP_S denote the durations required for a linear course and a semester course to reach completion, respectively. We may assume that CP_l is much smaller than CP_S (i.e., a linear course requires much less time for

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learners to complete compared with a regular semester course). In Fig. 1, the values of CP_1 and CP_2 are 5 and 25, respectively. We may conclude from Fig. 1 that typical online linear courses accommodate the learning needs of more students than typical semester courses do within a fixed period of time.

The issue may be more complicated; for example, different courses may continue for different numbers of weeks. Some courses may be canceled because of low student enrollment.

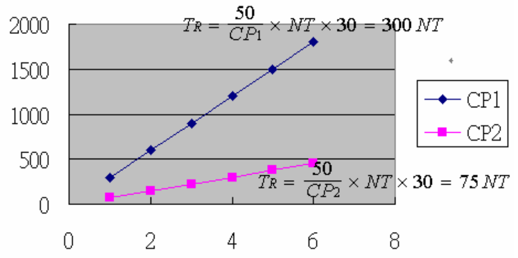

Figure 1. Graph of T_R against NT.

Our main aim was not only to increase the number of registered students, but also to increase the opportunities for just-in-time learning; we expected more learners to complete their intended learning plans without excessive delays. For example, an institution offers a course on Java in the fall of 2015; 1500 students register for this course, but another 2500 students are unable to enroll in this course until the spring of 2016 due to the lack of instructors. Between 2015 and 2016, the unregistered students who intend to learn Java must either wait or enroll in Java courses offered by other institutions. When the same Java course is offered again in the spring of 2016 by the original institution, the demand for that course will be lower. If the course is offered online linearly, a larger pool of learners will be able to enroll in the course without waiting until the spring of 2016.

Learners often need to enroll in a variety of courses. The offering of online courses is much less affected by limited resources than on-campus courses (e.g., a limited number of classrooms and laboratories). For resources that are specific to online courses, linear course offerings distribute student needs evenly over a longer period of time instead of causing a burst of needs in a short timeframe. Therefore, learners have more course options and more flexible learning schedules.

II. Related Works

Online degrees have been offered by accredited universities. The time needed to complete an online course is no longer limited to a regular semester [3]. A Massive Open Online Course (MOOC) is similar to a linear course and includes a serialized curriculum [4]. A serialized curriculum restricts students to enrolling in only one linear course at a time. Each linear course continues for a period that is shorter than the duration of a comparable regular course (e.g., material that might be covered in one semester in a typical classroom might be covered in 5 weeks in a linear course). This restriction simplifies the design and analysis of serialized curricula.

A. Allocation of Resources in a Virtual University

Learning in a virtual university is much more flexible than in a traditional university [5]. Analysis of the resources required to build a virtual university determined that the cost of establishing an academic program for 2000 students around the world would be less than that of adding a single classroom building on a physical college campus [6]. The flexibility of online learning can minimize costs for educational service providers. In this paper, we propose a pipe model to increase the use of resources, enabling online just-in-time learning, thus enabling more students to complete their learning goals in a shorter timeframe.

B. Construction of a Flexible Curriculum

In the present study, the flexibility of a curriculum was promoted by adopting linear courses. In general, a linear course requires a shorter time to complete than a semester course does. In other words, the knowledge and skillsets required for a specialized training program should be finer-grained than those required for a general course. For implementing a serialized curriculum, a regular semester course must be divided into several linear courses.

The set of linear courses for which a degree or certification is awarded must be sequenced into a serialized curriculum. After the required content of a curriculum has been established, all the knowledge and skills must be organized into a sequence. MOOCs operate in a manner that is similar to our approach [7]. A nanodegree can be implemented in linear courses and serialized curricula [8]. The prefix “nano” refers to the fine-grained partitioning of the educational content.

III. Pipe Model

We propose a pipe model to provide a basis for describing the system of online courses. In this pipe model, the coursework is described by a curricular graph that represents online linear courses as nodes and represents relationships as edges between a parent node and child node. Each learner follows a learning path through the curricular graph and completes a training regimen for a specialty.

A pipe is a path in the graph. A serialized curriculum is defined as a pipe in this pipe model. The weight of an edge represents the time needed to complete the course corresponding to the parent node. The weight is assigned to each course when the curricular graph is constructed. The sum of the weights along a serialized curriculum pipe is the time required to complete that curriculum. Fig. 2 illustrates a typical path in the pipe system. A total of 5, 2, and 4 weeks are required to complete courses C_1, C_2, and C_3, respectively.

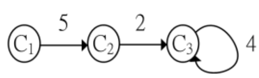

Figure 2. Typical path in the pipe system.

A. Problem of Resource Allocation

To optimize the traffic on the graph, strategies for offering online courses must be devised, and learner needs and preferences must be determined. The allocation of resources is intended to ensure that the number of students proceeding through the pipe is maximized without exceeding available resources. Given the limited resources, learners must be directed to proceed through the pipe evenly. Traditional semester courses usually generate bursts of need for faculty, and traditional schools often operate with a faculty shortage. Without adequate faculty, the quality of instruction decreases. The pipe model provides a simplified view of resource allocation.

B. Sequence of Learning Experience

The sequences of possible learning experiences are defined by the directed edges of the curricular graph. Fig. 3 displays eight courses. The prerequisites for Course B include Courses A and F. In the pipe model, we define a serialized curriculum as a path in the curricular graph. If the curriculum must cover all eight courses, then we should search for a valid topological type of the curricular graph. In Fig. 3, a valid topological type does not exist without adjustment.

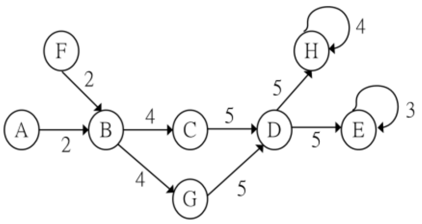

Figure 3. Curricular graph.

In Fig. 4, we adjust the graph by deleting edges (F,B), and (B,G), and adding edges (F,A), (C,G), and (H,E). The topological type of the curricular graph is also a path. This is not the only method of adjusting the graph. The adjustment should conform to the design goal of the curriculum. The horizontal design of the curriculum considers the scope and integration of content types, and the vertical design addresses the continuity and sequence of content modules.

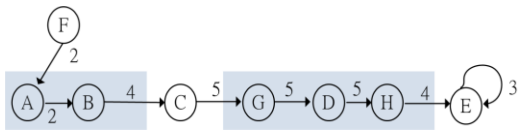

Figure 4. Adjusted curricular graph.

The pipe model provides a platform for the design of online curricula. Every path in the curricular graph may be a possible curriculum. The intersections of paths correspond to the courses that are common to multiple curricula. More faculty resources are needed for such courses if related curricula are offered simultaneously.

IV. Implementation and Analysis

A strong academic program must be supported by adequate faculty. Linear courses are offered online. Participating learners and instructors should become accustomed to online interaction. As in traditional classrooms, online faculty must demonstrate expertise in the subject matter of the curriculum. Unlike in traditional classrooms, online faculty must learn to teach with a different set of tools and skills. An online course or curriculum should enable just-in-time learning during its life cycle. Students who preregister for online courses help resource managers to plan for budgetary and human resource needs. The planning can be conducted with simulated or real data from the pipe system. For implementing data sources, existing information technology is sufficient for developing appropriate applications. In the present paper, we develop a theoretical foundation for the pipe model.

A. From Linear Courses to Serialized Curricula

The design of the curriculum starts with determining the content that must be taught. The content may be organized at the course level or the learning goal level. The courses or learning goals are treated as nodes, and the edges are defined by the relationships between the nodes. Once the nodes and edges have been decided, the curricular graph can be drawn. Whether a path in the graph can become a curriculum is determined by the learning needs or the skillset required for a specialty. In Fig. 5, the two dotted lines delineate two possible curricula (i.e., A->B->C->D->E and F->B->G->D->H).

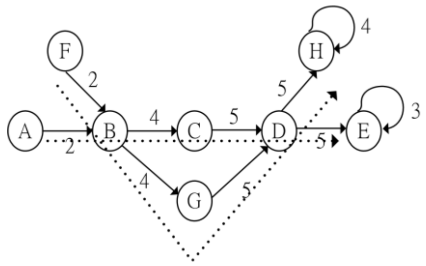

Figure 5. Valid curricula in a curricular graph.

Because numerous traditional universities have started to offer online courses, new online curricula are often designed on the basis of existing courses. We may start by building a curricular graph from existing courses and attempt to locate possible curricula.

B. Support for Just-in-Time Learning

A curricular graph can be adjusted in various ways. The following optimization constraints and optimization function provide criteria for allocations that support just-in-time learning without exceeding the limit of available resources. The total number of required faculty should not exceed the total number of faculty at any time.

$$\text{Optimization constraint: } \sum_{i=1}^{n} \frac{CS_i}{N_i} \le \sum_{i=1}^{n} c_i \qquad (2)$$

Given $1 \le i \le n$, c_i is the total number of available faculty for Course i, N_i is the class size for Course i, and CS_i denotes the number of students who have registered for Course i. The amount of faculty required for any course should not exceed the amount of faculty who can teach the course.

$$\text{Optimization constraint: } \frac{CS_i}{N_i} \le c_i \text{, for each } I \quad (3)$$

Our aim was to maximize the following objective function without breaking the optimization constraints. Other factors must be considered for constructing the model to enable this model to serve as an analytical tool to assist in improving our decision making; for example, we must consider what type of curriculum should be offered most frequently, and when recruiting faculty, we must consider what specialties are needed.

$$\text{Objective function: } \sum_{i=1}^{n} CS_i \quad (4)$$

An effective curriculum design should increase the retention rate. Once all the curricula are established, the pipe model generates a complete curricular graph. Each learner completes a journey of learning on the graph. By mining the course registration database, we can determine whether the resource allocation plan meets the entrance requirements.

The pipe model can be further extended by adding more attributes to nodes and edges; for example, if numerous faculty members are available for a course, then the corresponding node can accommodate more traffic. The status of learners should also be recorded in databases to enable the management of flow and congestion issues according to actual data.

C. Preliminary Analysis

The pipe model can aid in the design of serialized curricula for online linear courses. For management purposes, most people prefer a process-oriented description of what actions should be undertaken and when. Most institutions plan the life cycles of curricula and online courses through the following phases.

- A cost-efficiency analysis of existing curricula must be performed: an institution must balance yearly budgets and leave sufficient resources for long-term development. This is a prerequisite that must be considered before any other planning.
- Planning of strong curricula that meet the needs of learners: offering courses without substantial planning results in weak curricula that are likely to lower the retention rate. Strong curricula prepare learners for the rapidly changing job market by providing them with practical skills as well as in-depth specialization.
- Plans must achieve efficient use of resources: an institution must ensure that resources are established and in use. The quality of online courses is affected by the use of resources (e.g., faculty and network bandwidth).
- Plans must quickly be adjusted to changes: changes caused by internal or external factors should be addressed with sufficient speed to avoid damage to learners or the institution.
- Technology must be adequate: institutions with at least 100,000 students can be termed heavily populated or "mega-level" [9]. Technology enables these heavily populated schools to manage the activities and data associated with their student bodies.

The pipe model can provide strong support for the tasks described in the present work. The model is also useful for MOOC curriculum design. For MOOC platforms, the number of courses is large, and the systematic method through which the pipe model presents courses and curricula can be useful for planning and allocation of instructional resources.

V. Conclusion

An online curriculum can be planned by using the proposed pipe model to offer insight prior to sizable monetary investment. The notions of linear courses and serialized curricula enable the management of online courses to be scaled for heavily populated virtual universities. The present study explored course management issues in virtual universities.

The pipe model can be used as a tool for allocating resources in a massive open learning environment. From a learner's perspective, a learning schedule that can be flexibly planned is likely to maximize the benefit of the skills learned. Furthermore, the manner in which instructional media are provided to learners is also a crucial factor for success. Researchers have attempted to build a video database for hypertext-style browsing [10] through a mechanism known as e-Video. Learning goals can be hyperlinked, and interactive online instruction can be integrated with video databases and mobile technology to provide a resource-abundant virtual campus that enables effective learning.

While educational content can be delivered through multiple channels, schools must provide just-in-time learning for online learners. The number of online courses and the potential combinations of these courses are increasing. The pipe model can be used to locate potential curricula and enable human designers to make effective curriculum design choices.

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