ADAPTIVE LEARNING: DILEMMAS OF AUTOMATED INSTRUCTION IN POSTSECONDARY EDUCATION

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ABSTRACT

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American higher education is experiencing a time of extraordinary change where traditional practices that have remained relatively unchanged for decades are being questioned and altered in the face of declining public confidence in higher education. Higher education institutions are turning to technological innovations to address numerous concerns, essentially remaking processes and practices at various levels of higher education such as instruction, learning, and administration. Adaptive learning is one of the latest forms of innovation in teaching and learning, and it is currently receiving a great deal of attention across higher education. This study brings together the historical context, current environment of higher education, and the business market, and presents problems and dilemmas that may well affect the future of adaptive learning with the hope that it aids administrators, faculty, and staff in decision-making about this innovation in postsecondary education.

This dissertation is dedicated to my wife and daughter.
Thank you for all your love and support.

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INTRODUCTION

American higher education is experiencing a time of extraordinary change where traditional practices that have remained relatively unchanged for decades are being questioned and altered in the face of declining public confidence in higher education (Altbach et al., 2009; DeMillo, 2015). Rising costs and the declining quality of higher education, combined with pressures from global economic changes, have Americans questioning the value of a postsecondary education. This scrutiny has resulted in reduced spending on public institutions and declining applications for many private institutions (DeMillo, 2015). In this revolution of sorts, higher education institutions are turning to technological innovations to address these and other public concerns, essentially remaking processes and practices at various levels of higher education such as instruction, learning, and administration. Unfortunately, one notable aspect of technological innovations over the last two decades is "the degree to which excitement about innovations has failed, in many respects, to meet optimistic expectations" (Altbach et al., 2009, p. 121). Innovations often entice higher education institutions with multitudes of hopeful possibilities, but oftentimes do not achieve those goals once implemented; therefore, innovations in higher education necessitate in-depth study to aid faculty, administrators, and staff in decision-making surrounding innovation.

Innovation is the successful introduction of an idea, product, or method that a particular individual or group finds novel and where its use advances change (Evans & Leppmann, 1968; Serdyukov, 2017). It is an instrument that is necessary for the continuous evolution of industries towards sustainable futures. However, there is a point of caution with innovation: innovation can yield positive, negative, or no consequences, but we tend to only see the good in innovation (Morozov, 2013). Evgeny Morozov (2013), a researcher into the political and social

implications of technology, warns that "the problem is this: since innovation is seen as having only positive effects, few are prepared to examine its unintended consequences; as such, most innovations are presumed to be self-evidently good" (p.167). Innovation in higher education is particularly important due to the significant role higher education plays in the advancement of economies, societies, and individuals (Altbach et al., 2009; Morozov, 2013). It is, therefore, vital to study individual innovations in higher education, identifying their many consequences without assuming that they will only yield positive consequences. These studies must include research into the history, environment, and impact of the innovation in higher education as "universities—especially public, but private universities as well—always operate in a country-specific political and economic context as well as in an historical context and an increasingly globalized international context" (Altbach et al., 2009, p. 73). It is also "misleading to discuss technological innovation in isolation from business innovation, since each enables the other" (DeMillo, 2015, p. 83). In all, studies on innovation in higher education should be critical, consider the history and current environment of the innovation, and be tailored towards achieving an understanding of the consequences of its use.

One particular innovation that has been highly touted as a potential education game-changer by individuals, businesses, and governments is adaptive learning, but it is lacking critical study (J. King & South, 2017; Murray & Pérez, 2015; Newman, Stokes, & Bryant, 2013). Described in-depth in the following chapter, adaptive learning is *a form of technology-based personalized learning that takes a sophisticated, data-driven, and sometimes non-linear approach to instruction that adjusts content based on each learner's interactions, including background, performance, and abilities.* It is one of the latest forms of technological innovation in teaching and learning, which some believe has the potential to address many of the issues in

question about higher education, including cost, quality, and access (J. King & South, 2017; Murray & Pérez, 2015; Newman et al., 2013; Vignare et al., 2018). Adaptive learning only recently entered wide-scale higher education practice, largely due to advancements in technology that have made it easier to develop and use, an economy which is demanding change to higher education, and the shift to market and market-like behaviors of higher education institutions (Murray & Pérez, 2015; Slaughter & Rhoades, 2004). Still, with all the attention on adaptive learning, information on this teaching and learning innovation remains fragmented and lacking critical insight.

This study brings together the historical context, current environment of higher education, and the business market, and presents areas that may affect the future use of adaptive learning to aid in decision-making for public and private research institutions. Since the development and success of innovation in higher education is highly dependent on the environment and actors involved, this study uses a sociocultural view of the institutionalization of adaptive learning, which posits that the drivers and criticisms of adaptive learning stem from the relationships between higher education, the state, and the economic market as it becomes part of higher education institutions (Vargo, Wieland, & Akaka, 2015). In this sociocultural view, "innovation does not automatically occur when firms, or even networks of firms, introduce new ideas or develop new *products* that meet preexisting, though sometime latent, market demands" (Vargo et al., 2015, p. 66); rather, "both technological and market innovation involve the active participation (e.g., enactment of practices and determination of meaning) of firms and customers, as well as other actors" (2015, p. 66). From this view, the value of adaptive learning as an innovation in higher education is being shaped by institutional and economic actors with their own reasons to do so, while at the same time, the innovation is subsequently shaping higher

education. This study recognizes academic capitalism as a primary reason for the drivers and criticisms of adaptive learning, which in turn, have shaped and are continuing to shape the development of adaptive learning. By identifying academic capitalism as the sociocultural driver for adaptive learning as an innovation, the history, present state, and ongoing dilemmas of adaptive learning are presented in relation to the market and market-like behaviors of higher education, government, and business actors.

CHAPTER 1

Institutionalization is the "the maintenance, disruption and change of institutions" (Vargo et al., 2015, p. 64) from the introduction of an initiative or object. It "involves an object first being recognized, then accepted by relatively few actors, and then widely diffused and broadly accepted within a field" (Lawrence & Suddaby, 2006, p. 247). The institutionalization of an innovation is the incorporation of the innovation into the established culture of an institution or field. This incorporation has an effect on the institutions and fields as well as on the innovation itself (Vargo et al., 2015). In the case of adaptive learning, the interactions between groups of actors shaped and continues to shape adaptive learning and the institutions where it is used, making the motivations and any environmental factors influencing those actors especially important. In the evolution of adaptive learning in higher education there are two interdependent influences that have shaped adaptive learning and their institutions: the knowledge economy and academic capitalism. This chapter introduces these two concepts and proposes a working definition of adaptive learning in the absence of a unified definition in business or higher education.

The Knowledge Economy, Academic Capitalism, and Adaptive Learning

At the turn of the 21st century, a shift in U.S. industry toward advancements in science and technology led to the proliferation of knowledge as a key factor in economic development (Adler, 2001; D. H. C. Chen & Dahlman, 2005; Crow & Dabars, 2015; Olssen & Peters, 2005). Knowledge, as a near-endless resource that only grows with use, became a cornerstone for the growth and development of businesses and entire industries starting in the late 1980s (Adler, 2001; Crow & Dabars, 2015; Powell & Snellman, 2004; Slaughter & Rhoades, 2004). This large-scale move toward the creation, application, and distribution of knowledge, which still

dominates U.S. industry and global development, was designated the *knowledge economy* (Hancock, 2019). This term describes the economic framework that highlights the integral use of knowledge to generate prosperity (Hancock, 2019; Slaughter & Rhoades, 2004). It is characterized by a change from reliance on physical inputs or natural resources to intellectual capabilities that lead an accelerated pace of advancements in science and technology, as well as rapid obsolescence (Powell & Snellman, 2004). Ecommerce, mobile phones, and personal computers benefited substantially from the evolution of the knowledge economy in the mid- to late 1990s. Innovation across many fields, including biomedical, information and communication technologies, and transportation, became an expectation for individual businesses to remain viable and resulted in valuable contributions to economies and societies as a result of the knowledge economy. This time period also saw the rapid decline of well-established technologies such as typewriters, rotary phones, and film cameras due to the accelerated pace of technology growth.

As the knowledge economy grew, key actors in the development of knowledge—including higher education—became invaluable to the success of the U.S. economy (World Bank - IBRD, 2003). Higher education was seen by state and federal governments as playing a critical role in the knowledge economy, and universities were encouraged to build ties with businesses and society in general (Olssen & Peters, 2005; Slaughter & Rhoades, 2004). Specifically, jobs created in the knowledge economy required an educated workforce, as "technological innovations require[d] workers with complementary skills and knowledge of that technology" (Powell & Snellman, 2004, p. 213). Governments saw an opportunity to build this workforce by encouraging ties between higher education and the market, also called the free market, which is defined as an economic system operating by free competition in supply and demand, such as the

for-profit behaviors of businesses and corporations ("Free market," 2019). However, these relationships triggered noticeable changes in higher education, government practices, and the market.

While most of the literature on these changes focuses on individual organizations, some researchers have begun to look into the relationship as a complex environmental network of actors, organizations, and the market—the sociocultural environment (Slaughter & Rhoades, 2004). An analysis of the relationships between higher education and society in this new economy led Slaughter and Rhoades (2004) to develop the *theory of academic capitalism*. The theory of academic capitalism "sees groups of actors—faculty, students, administrators, and academic professionals—as using a variety of state resources to create new circuits of knowledge that link higher education institutions to the new [knowledge] economy" (Slaughter & Rhoades, 2004, p. 1). It is a theory that demonstrates ways in which relationships between higher education, the state, and the economic market are changing structures and behaviors between each other (Cantwell & Kauppinen, 2014).

For higher education institutions, Slaughter and Leslie (1997) distinguish between two types of behaviors that define academic capitalism: market-like behaviors, which are academic behaviors that closely mimic the free market; and market behaviors, or for-profit activities by educational institutions (Park, 2011). Market-like behaviors include faculty and institutional competition for external funding such as university-industry partnerships, endowment funds, and fee increases for students (Park, 2011). Market behaviors include patenting, spin-off companies, and licensing royalties (Park, 2011).

Slaughter and Rhoades (2004) shed light on their theory by stating that the "theory of academic capitalism focuses on networks—new circuits of knowledge, interstitial organizational

emergence, networks that intermediate between public and private sector, extended managerial capacity—that link institutions as well as faculty, administrators, academic professions and students to the new economy" (2004, p. 15). Coupled with the investment, marketing, and consumption behaviors of higher education, Slaughter and Rhoades (2004) labeled these behaviors and mechanisms the *academic capitalist knowledge/learning regime*. The academic capitalist knowledge/learning regime is the environment that currently dominates higher education, where the structures and behaviors of higher education place greater value on its connection to the knowledge economy than to the public good.

The majority shift to the academic capitalist/knowledge regime in the knowledge economy came at the expense of the traditional *public good knowledge/learning regime*. The public good knowledge/learning regime is based on the discovery of knowledge within academic disciplines, which was then valued as a public good with public benefits (Slaughter & Rhoades, 2004). The public good knowledge/learning regime assumed a robust separation of the private and public sectors, where the private sector valued knowledge privatization and the public sector valued knowledge sharing (Slaughter & Rhoades, 2004). While the academic capitalist/knowledge regime currently dominates decision-making in higher education, it continues to coexist with the public good knowledge/learning regime (Slaughter & Rhoades, 2004). Some faculty and administrators are still guided by and passionate about the public good of higher education, which is a clash that creates worry in some and elicits strong reactions in others.

The rise of the academic capitalist knowledge/learning regime blurred the separation that existed between higher education, the state, and the market in the public good model, prompting the transformation of knowledge to a private good (Slaughter & Rhoades, 2004). The theory of

academic capitalism stands out in the study of higher education because "in contrast to literatures that focus on 'the' organization or on research relations between universities and industry, construed as separate organizational spheres, we look at networks of actors that cross boundaries among universities and colleges, business and nonprofit organizations, and state(s)" (Slaughter & Rhoades, 2004, p. 9).

The shift to the academic capitalist knowledge/learning regime has resulted in two major elements: (1) there are now policies and governance practices that restructure higher education systems and organizations, linking them to the state and the market; and (2) policymakers, faculty, administrators, and students take on market or market-like actions (Cantwell & Kauppinen, 2014). The theory "does not see the university as being 'corporatized' or subverted by external actors" (Slaughter & Rhoades, 2004, p. 1) as some believe it suggests. Instead, academic capitalism stipulates that structural and behavioral changes within higher education stem from actions proactively taken by higher education rather than imposed on it by other actors (Cantwell & Kauppinen, 2014). Academic capitalism, therefore, describes changes that are self-driven by higher education faculty, administrators, and students, which embrace market and market-like activity that could be resisted or neglected, if desired (Slaughter, 2014). Changes, such as the current drive by some institutions, governments, and market organizations to develop and adopt adaptive learning, can be described by the theory of academic capitalism.

The theory of academic capitalism provides a "framework for understanding the contemporary social, political, and economic conditions of higher education" (Cantwell & Kauppinen, 2014, p. 3). Its ability to describe relationships in the knowledge economy between groups of actors in higher education and the structural and behavioral changes within higher education makes it a valuable guide for studying the innovation of adaptive learning. The

adaptive learning movement simply refers to the current time in higher education when adaptive learning technologies are thriving in education. This movement has steadily ramped up since the mid-2000s, beginning with its use in K-12 education and then making its way into higher education a short time later. Today, developments in educational technologies facilitated by the knowledge economy, such as online learning, learning management systems, and Massive Open Online Courses (MOOCs), are advancing the use of adaptive learning systems in higher education. Without these technologies, the adaptive learning movement would not be possible. Additionally, the relationships between higher education and market actors, such as courseware publishers and not-for-profit organizations, continue to support the institutionalization of adaptive learning in higher education.

The adaptive learning movement began from the links between the knowledge economy and higher education. Following the history of adaptive learning, contributions to the learning sciences and technology in the knowledge economy evolved the mid-20th century idea of a system that adapted to an individual learner's needs into what we now call adaptive learning. The next chapter dives into the development of adaptive learning as we know it today. Beyond the science and technology, behavioral and structural changes in higher education, driven by governments and the market, have led to the adoption of adaptive learning at a mounting pace—or the adaptive learning movement. I use academic capitalism to describe the history, development, and impact of adaptive learning, as well as facilitate predictions of the future of adaptive learning in higher education.

The knowledge economy was the catalyst for the adaptive learning movement and academic capitalism was its gateway into higher education. Several of the drivers and criticisms for the adaptive learning movement in higher education originate from the motivation to either

promote or push against academic capitalism. What started off as an idea for improving learning through adaptive personalization has become a sweeping teaching and learning movement for change in higher education based on an innovation, and the links between higher education, governments, and the market made it possible.

What is Adaptive Learning?

While use of the term adaptive learning is widespread today, there is little consensus on a single definition. A large contributing factor to many of the variations is that adaptive learning is still evolving, and with every new study, actor, or technology in the field, the definition can change (Alexander et al., 2019). Several researchers and education interest groups, such as EdSurge, Educause, and Tyton Partners, have recognized the importance of a common definition. However, each set out independently to establish a definition, which further distanced them from their goal as each developed a different definition (EdSurge, 2016; Horn, 2016; Newman, Bryant, Fleming, & Sarkisian, 2016; Waters, 2014). Despite the variety of definitions, commonalities exist between them that can help build an understanding of what adaptive learning is.

In this section, I compare a few recent definitions in order to establish a general picture of what adaptive learning means today. For the purposes of this study, "recent" is defined as beginning in 2013, which is when various studies and articles began referring to adaptive learning as "emerging" and "revolutionary" in higher education (Means & Anderson, 2013; Newman et al., 2013; Peter Stokes, 2013; Webley, 2013). This year also marks the beginning of the adaptive learning movement, when the pace of adaptive learning development and implementations began to accelerate.

Current Definitions

Adaptive learning as we know it today owes much of its success to the Bill & Melinda Gates Foundation (Zimmer, 2014). The Bill & Melinda Gates Foundation and Tyton Partners published a report in 2013 titled *Learning to Adapt: A Case for Accelerating Adaptive Learning in Higher Education*, which made the case for using learning software that adapts to student levels in higher education (Newman et al., 2013). The report and the foundation's reputation for influencing social change prompted several groups and higher education institutions to take a close look at adaptive learning. In the 2013 report, adaptive learning is defined as "a more personalized, technology-enabled, and data-driven approach to learning that has the potential to deepen student engagement with learning materials, customize students' pathways through curriculum, and permit instructors to use class time in more focused and productive ways" (Newman et al., 2013, p. 4).

In 2013, The U.S. Department of Education Office of Educational Technology defined adaptive learning in terms of the new capabilities of digital learning systems by explaining that:

> Digital learning systems are considered adaptive when they can dynamically change to better suit the learner in response to information collected during the course of learning rather than on the basis of preexisting information such as a learner's gender, age, or achievement test score. Adaptive learning systems use information gained as the learner works with them to vary such features as the way a concept is represented, its difficulty, the sequencing of problems or tasks, and the nature of hints and feedback provided. Adaptive instruction is related to individualized, differentiated, and personalized learning. Minimally adaptive learning systems offer individualized pacing, whereas more sophisticated systems differentiate the nature of learning activities based on student

> responses. Systems are now being developed to support personalized learning by incorporating options for varied learning objectives and content as well as method and pacing of instruction. (Means & Anderson, 2013, p. 27)

In *Adaptive Learning Systems: Surviving the Storm*, Lou Pugliese (2016) notes that there are many ways in which adaptive learning systems are described, typically by industry. He states that "while classifications in other industries are narrower in defining their specific applications and use cases, there are no specific guidelines, taxonomies, or common vernacular for how various types of adaptive capabilities are described in the edtech industry" (Pugliese, 2016, para. 7). He goes on to offer a general idea of the defining characteristics of adaptive learning by stating that "at minimum, adaptive systems are composed of methods that organize modular content to be learned, multiple systems of assessment that track and evaluate students' abilities, and techniques of matching the presentation of content to individual learners in dynamic and personalized ways" (Pugliese, 2016, para. 15).

The 2016 follow-up report from Tyton Partners and the Bill & Melinda Gates Foundation, *Learning to Adapt: The Evolution of Adaptive Learning In Higher Education*, stated that "adaptive learning has gone from an ill-defined concept in higher education to an important category of teaching and learning technology" (Newman et al., 2016, p. 4). The report goes on to explain that in the three years since the first publication, the applications of adaptive learning technology expanded, adaptive products started building new features in response to institutional demand, and adaptive learning became a relevant option for competency-based education (Newman et al., 2016). In the report, adaptive learning is defined as "solutions that take a sophisticated, data-driven, and in some cases, nonlinear approach to instruction and remediation, adjusting to each learner's interactions and demonstrated performance level and subsequently

anticipating what types of content and resources meet the learner's needs at a specific point in time" (Newman et al., 2016, p. 3).

Recent definitions begin to mostly repeat the same terminology as previous definitions, but start to include words that show the continuing evolution of adaptive learning. The following definition by Moskal, Carter, and Johnson (2017) uses the terms "algorithms" and "various media," which are becoming common terminology about complex systems like adaptive learning:

> Adaptive learning is one technique for providing personalized learning, which aims to provide efficient, effective, and customized learning paths to engage each student. Adaptive learning systems use a data-driven—and, in some cases, nonlinear—approach to instruction and remediation. They dynamically adjust to student interactions and performance levels, delivering the types of content in an appropriate sequence that individual learners need at specific points in time to make progress. These systems employ algorithms, assessments, student feedback, instructor adjustments/interventions, and various media to deliver new learning material to students who have achieved mastery and remediation to those who have not. (Moskal et al., 2017, p. 1)

Defining Characteristics

While there are numerous other definitions, the provided examples lead to an overall understanding of what adaptive learning means today. This understanding is constructed from a few key concepts that stand out as consistent, in some form or another, through the progression of adaptive learning definitions. Specifically, a majority of the definitions include the following six concepts: personalized learning, technology-based, data-driven, non-linear/complex, adjusts

content, and learner interactions. This section provides more details on each of the concepts as they relate to adaptive learning.

Personalized learning.

The concept of personalized learning is a fundamental element in adaptive learning. Adaptive learning is an educational *method* that utilizes the personalized learning *approach*. An approach is the overall philosophy or belief that one adopts to face a certain subject or issue, while a method is the set of procedures or ways in which the approach is used (Hofler, 1983). Adaptive learning is one way in which personalized learning is used in teaching and learning.

Personalized learning is an educational approach that aims to tailor instruction to a learner in a way that best promotes knowledge acquisition. It "seeks to accelerate student learning by tailoring the instructional environment—what, when, how and where students learn—to address the individual needs, skills and interests of each student" (Douglass & DeLeon, 2014, p.46). It is one of multiple approaches to teaching and learning, such as project-based learning and the flipped classroom.

In education, the terms *personalization* and personalized learning are used interchangeably (Starr, 2018). This can cause some confusion since personalization has several meanings across industries and contexts. The three most common uses for the term personalization are in business, information science, and education. In business, personalization refers to the concepts of one-to-one marketing or personalized products, where marketing practices or products are "tailored to a group of individual customers rather than to the entire population" (Kim, 2002, p.31). The application of personalization in business is that by understanding the attitudes, preferences, and needs of the customer, marketing campaigns and products can be targeted at individuals to increase revenue (Kim, 2002).

In the field of information science, personalization is the delivery of tailored information using criteria such as timeliness, relevance, and importance (Fan & Poole, 2006). Simply put, personalization means "to deliver information that is relevant to an individual or a group of individuals in the format and layout specified and in the intervals specified" (Kim, 2002, p.30). The personalization of information is especially relevant in the use of internet and communications technologies (ICT) due to the vast amount of information available on the internet today. One of the primary drivers in the preference for personalized experiences is information overload, or the perception of information overload (Devaney, 2014). With personalization: "you aren't presented with thousands of resources to sort through and consume. Instead, you are–ideally–presented with exactly the information you were looking for. Hence, you never feel 'overloaded' with information" (Devaney, 2014).

In education, personalization means personalized learning, or focusing the purpose of education, providing an instruction service based on information unique to an individual. Use of the term personalization is still widespread, particularly in information and studies prior to 2014, but personalized learning has become the preferred term since then (Starr, 2018).

The origins of personalized learning.

The basic tenets of personalized learning are traceable back to the social and political philosopher Jean-Jacques Rousseau in the 1700s and to the philosopher educator John Dewey in the early 1900s (Yonezawa, McClure, & Jones, 2012). Both Rousseau and Dewey are cited as having first identified possible counters to the instructor-led passive approaches to education in their times by promoting individual knowledge acquisition through personalization.

Rousseau, in his 1762 book *Emile, or On Education*, promoted an approach to education that was tailored to the experiences and needs of the individual learner (Rousseau, 1979). Emile,

the title character in the book, is encouraged by his tutor to explore the world in a structured environment formed around his needs. The environment described by Rousseau as an ideal learning atmosphere outlines the beginnings of a personalized learning environment meant to provide meaningful interactions with content (Regan, 2016). In 1902, John Dewey promoted building on learners' interests and incorporating outside experiences to meet individual learner needs in his book *The Child and the Curriculum* (Dewey, 1902). Building on a learner's interest to promote knowledge acquisition is a main component of personalized learning.

Modern interpretations of personalized learning are largely based on the work of Theodore Sizer, with some contributions by his colleagues at the Coalition for Essential Schools (CES) (Yonezawa et al., 2012). In a 1983 study that suggested improvements to high schools, Sizer recommended that "teaching and learning must be personalized to the greatest extent possible" (Sizer, 1983, p.37), asserting that the gains in knowledge acquisition and effectiveness far outweighed the costs associated with shifting toward a personalized approach. Personalized learning was a central charge for CES when Sizer launched it in 1984. CES promoted the adoption of principles to personalize by calling for schools to reduce teacher ratios and encourage learner-centered approaches (Yonezawa et al., 2012). Unfortunately, reducing teacher ratios in higher education meant increasing expenses by adding more instructors or reducing revenue streams by admitting fewer learners, making this an unpopular idea.

Technology based.

Although it was not always the case, the idea that adaptive learning is technology-based developed as the knowledge economy matured. Prior to the 1990s, adaptive learning was by and large a theory for the use of personalized learning with very few practical applications. These applications of adaptive learning before the knowledge economy are covered in detail in the next

chapter. During the pre-knowledge economy time, the delivery of adaptive instruction relied on human means and/or technology. However, technology was expensive and not as advanced as it is today. Adaptive learning via technology remained accessible to very few researchers or individuals. During early days of the knowledge economy, between the 1990s and the early 2010s, technology in education advanced by leaps and bounds. During this period, personal computers, online learning, and learning management systems—all key technologies in adaptive learning today—developed to the point where the delivery of dynamic or adaptive content was more efficient and effective through the use of technology. By 2013, adaptive learning became entrenched in the use of technology as the primary way it is implemented.

This shift towards considering adaptive learning as a technology was described in a 2013 report from the U.S. Department of Education's Office of Educational Technology. The report stated that "advances in technology have heightened the possibility that digital learning systems can replicate dynamic adaptations used successfully by human tutors or even implement those and other methods more effectively than humans" (Means & Anderson, 2013, p. 28). In essence, while it could be done by humans, technology had outpaced the ability of humans to deliver adaptive learning. Adaptive learning is now commonly referred to as an educational technology, which is defined as "the approach of applying our scientific knowledge about human learning to the practical task of teaching and learning" (Heinich, Molenda, & Russell, 1985, p. 5). It is effectively a combination of the definition of technology and the primary tasks of education, teaching, and learning. The current adaptive learning movement assumes that adaptive learning is an educational technology that uses the personalized learning approach.

Data-driven.

Adaptive learning is heavily data-driven (Howlin & Lynch, 2014). It relies on information from the learner and about the learner to determine the starting point, presentation, pace, and other aspects of the content. An adaptive learning system's "adaptivity is driven by frequent assessment and evaluation activities that result in nearly real-time adjustments in the instructional content, learning resources, and courses pathways presented to students" (Newman et al., 2013, p. 7). Frequent assessment builds a data-based model of the learner, which is then used as a guide for the adaptive learning system. More sophisticated adaptive learning systems "also aggregate cognitive and non-cognitive student data to support development of a learner profile; this profile may inform not only the sequencing and instructional content presented, but also its modality (e.g., text, video, simulation, audio), duration, frequency, timing, etc. to best align with individual learners' prior knowledge, cognitive ability, pace of learning, and motivation" (Newman et al., 2013, p. 7). The learner's background, interactions, performance, and abilities are all used as data points to drive adaptive learning systems.

The data component of adaptive learning is typically referred to as *learning analytics*, or "the measurement, collection, analysis and reporting of data about the progress of learners and the contexts in which learning takes place" (Sclater, Peasgood, & Mullan, 2016, p. 4). Learning analytics is a standalone field of study that builds on advances in data collection and processing technologies to turn raw data into information, which can then be used in decision-making, such as individual interventions when learners are preforming poorly.

Non-linear/complex and adjusts content.

Unlike a textbook, where content is organized via a linear and logical progression of knowledge, the progression through knowledge in adaptive learning is non-linear and complex.

Adaptive learning builds on insights from early work on artificial intelligence and intelligent tutoring systems that used *knowledge modeling* as a "way to organize curricular content by dividing it into a series of smaller, but conceptually interconnected, elements" (Ferster, 2014, p. 115). Knowledge models represent content in a web-like fashion, with concepts having multiple connections to other concepts, rather than the linear progression where divided content was presented linearly from one content portion to the next (Ferster, 2014). Figure 1 below demonstrates the difference between linear progression through content versus a knowledge model:

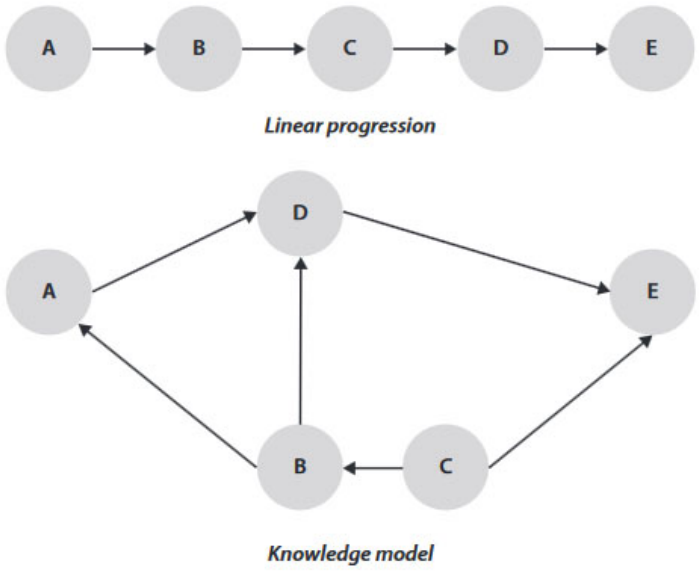

Figure 1: Linear progression versus knowledge model. Reprinted from *Teaching Machines* (p.116) by B. Ferster, 2014: Baltimore, Johns Hopkins University Press

Knowledge models in adaptive learning systems are referred to as *content models.* Content models are the way the topic, or domain, is structured, including detailed learning outcomes and defined tasks that need to be learned in adaptive learning systems (Oxman & Wong, 2014). In a linear progression, content has a specific starting point and ending point,

where these points and the flow of information between them are predetermined by the instructor for the learner (Robberecht, 2007). All learners must follow the designed flow, where "novice, intermediate, and advanced learners all begin at the same point, and proceed to the learning material in the same path" (Robberecht, 2007, p. 60), and only pace could differ if the learner progresses at a different pace. In adaptive learning content models, the responsibility for mastering a particular subject is placed on the learner, and the presentation of the content is determined by the system based on the learner. The instructor may provide general guidance and determine whether the learner has mastered the topic, but the learner is responsible for their own rate of learning and it is the learner, whether actively or passively, who determines the content (Robberecht, 2007).

In adaptive learning systems, the entry point into the content and the path the learner takes are determined using a complex analysis of assessment and data collected in the system. These statistical inferences about the student's ability to undertake topics, master sub-topics, and other complex considerations, such as cognitive learning style and motivational state, form what is called the *learner model* (Oxman & Wong, 2014). The learner model is the adaptive system's understanding of who the individual learner is. The adjustment of content for an individual student at a given time, or the combination of the content model and the learner model, is called the *instructional model* (Oxman & Wong, 2014). The instructional model is what determines how an adaptive learning system selects specific content. This instructional determination is made by the system, free from on-going and person-guided interaction. The content model, learner model, and instructional model are the three fundamental elements driving adaptive learning systems.

The way in which the adaptive learning system uses these elements is typically considered proprietary information. Unless the adaptive learning system is open-source, which grants users the ability to view the source code and make modifications as needed, the way in which the adaptive system goes about using the content models, learner models, and instructional models is not exposed (Lerner & Tirole, 2001). Often referred to as proprietary "algorithms," there have been recent calls to review how companies are using learners' personal data and how it is affecting education and learners (Boninger, Molnar, & Murray, 2017). The lack of information on how exactly learner data is used adds to the complexity of the topic and is one of the arguments against using adaptive learning systems.

Learner interactions.

At the core of adaptive learning systems is the individual learner. Learner interactions with the system are the primary source of data that drive adaptive learning systems. The learner interacts with the system in two ways: actively and passively. Active interactions include the learner's performance and abilities, such as answering questions, reading and accessing learning materials, communicating with other learners and instructors, and choosing when and how fast to go through the material. Passive interactions are ways in which adaptive learning systems build the learner model based on what they know about the student: their background, such as grade history, demographics, prerequisites, and other knowledge about the student that was not directly assessed by interacting with the learner but is still a way in which the learner is connected to the adaptive learning system. Both of these types of interactions affect how, when, and why the adaptive learning system chooses to present certain content. The continuous assessment that drives the back-end learning analytics of adaptive learning systems is entirely based on learner interactions (Howlin & Lynch, 2014; Oxman & Wong, 2014; Robberecht, 2007). For example,

if a learner is presented with a math question that the learner subsequently gets wrong, the adaptive learning system can provide information on why their answer is incorrect and give the learner the option to go back to the content, choose a new question, or ask for clarification. The adaptive learning system's assessment of the interaction, as well as the assessment of content mastery, further develops the learning model by providing data that will allow the system to determine the next steps it will follow.

Working Definition and Visualization

Combining each of the defining characteristics brings us to a working definition of adaptive learning for this study: adaptive learning is a form of technology-based personalized learning that takes a sophisticated, data-driven, and sometimes non-linear approach to instruction that adjusts content based on each learner's interactions, including background, performance, and abilities. A significant note in the establishment of a working definition of adaptive learning for this study is that this definition does not include the term *automated instruction*, as current definitions of adaptive learning, including those cited earlier in this chapter, do not include this term. Automated instruction refers to the use of technology to present data-driven non-linear content to educate learners with little to no ongoing interaction with instructor-led content, which originated in the mid-20th century (Carter, 1961; Ferster, 2014). While the term is not present in the working definition, all of the elements that define automated instruction—technology, data-driven, and non-linear—are indeed present. It stands to reason that adaptive learning is an advanced form of automated instruction. Recent global trends highlighting the advancement and fears of automation elicit the need to stress that adaptive learning is the automation of instruction (Schwab, 2016). This is the primary reason that the title of this study identifies adaptive learning as automated instruction.

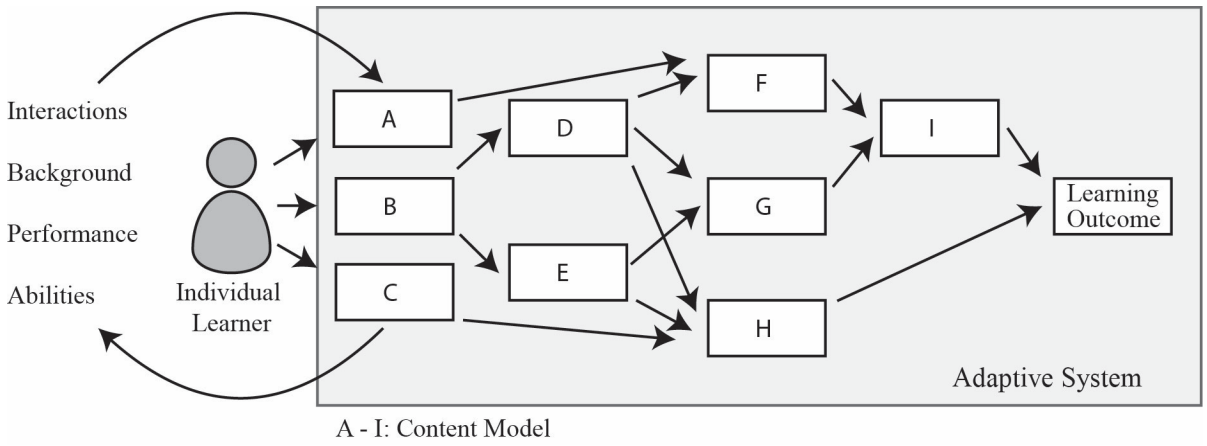

Figure 2: Model of the Definition of Adaptive Learning

In an effort to provide additional clarity on the definition of adaptive learning, Figure 2 shows a Model of the Definition of Adaptive Learning. It borrows visual components from studies on adaptive learning frameworks, such as the directed acyclic graph of knowledge items that make up the content model from Howlin and Lynch (2014), to provide a visualization of adaptive learning. The model shows the key elements within the definition of adaptive learning in this study including: personalized learning, shown by the presence of just one learner as a focal point in the model; data-driven, shown by the cyclical use of the learner's background, interactions, performance, and abilities; and non-linear approach, inferred from the multiple paths a learner can take toward a learning objective in the content model.

Using Adaptive Learning

In 2016, the Bill & Melinda Gates Foundation funded grants at seven institutions in the Association of Public and Land-Grant Universities (APLU) to implement and study the use of adaptive courseware, further advancing the adoption of adaptive learning. In 2018, the Personalized Learning Consortium at the APLU published *A Guide for Implementing Adaptive Courseware: From Planning Through Scaling,* which brought together the best practices from these seven partner institutions (Vignare et al., 2018). The guide is intended to serve as a

framework to jumpstart other institutions along the path to installing adaptive learning, and it provides valuable information on how adaptive learning is being and can be used.

Adaptive learning uses both adaptive learning systems, or platforms, and individual adaptive courseware. Adaptive courseware is a "digital instruction tool that provides a personalized learning experience for each student" (Vignare et al., 2018, p. iii) and includes all the assessments and course content, sequenced in a content model. An adaptive learning system is a platform on which to build and contain adaptive courseware. There are two options for adaptive courseware: off-the-shelf courseware and custom-built adaptive platforms. *Off-the-shelf courseware* are solutions sold by the course title and function as a supplement to the course as a textbook replacement. They offer ready-to-use content delivered through an adaptive learning system and typically do not allow for customizations in either content or assessment (Vignare et al., 2018). *Custom-built adaptive platforms* are solutions that allow users to build or import course content within one system and allow for integrations of original content, commercial content, and open educational resources (Vignare et al., 2018). With custom-built platforms, users have the option to build their own courseware or purchase course-development services from the vendor.

Adaptive courseware can be used across many disciplines and in a variety of classroom environments, such as face-to-face, online, flipped, and blended courses. There are many ways to integrate adaptive courseware into the course, so there is no one right way to do it. The following are examples by which to gain a general understanding on how it is used in each of the environment types: in face-to-face environments, adaptive courseware can be used in place of the textbook, supplementing instruction; in online environments, adaptive learning can be the system and method an online course is delivered, containing all lessons, media, assessments, etc.; in

flipped courses, adaptive learning courseware can be the method of delivery for instruction outside the classroom that can inform in-person discussions and work; and in blended courses, adaptive learning courseware would serve as web-based online learning.

In the next chapter, I go on to further delve into the history of adaptive learning. This builds a framework for understanding how adaptive learning evolved and how it is being used today. It also facilitates a discussion of the criticisms and drivers of this movement, and finally leads to a jumping point for predictions on the future direction and possibilities of adaptive learning in higher education.

CHAPTER 2

Adaptive Learning Before the Knowledge Economy

The adaptive learning movement is a product of the evolution of technologies and ideas over the course of time. Before the rise of the knowledge economy, adaptive learning was a series of ideas about the use of personalized learning in education based in the social sciences. While there were some minor applications of adaptive learning during this time, it was the rise of academic capitalism that set the stage for what we now call adaptive learning. The relationships between higher education, the state, and the economic market that have flourished under the knowledge economy shaped an environment where adaptive learning is both beneficial and feasible. Although a great deal of credit for the current adaptive learning movement goes to academic capitalism in the knowledge economy, the movement is only possible because of the groundwork laid before the knowledge economy took hold. This chapter details important innovations in the history of adaptive learning, centered on the transformation of early ideas through the use of educational technology, which set the foundations for adaptive learning as we know it today.

Early Educational Technology

Early forms of educational technology, such as the horn book (typically a sheet of printed paper pasted on a board introduced in 1467) and the textbook, centered on improvements to the way information was communicated to learners (Ferster, 2014). They also represented ways in which knowledge was captured and standardized for uniform instruction, an early form of *teacher-proofing.* Teacher-proofing "is the name given to the practice of limiting the autonomy of individual teachers to produce a more uniform and controlled experience" (Ferster, 2014, p.1). Because of its impact on the role of instructors, teacher-proofing is often cited as a reason for

rebuffing the advancement of technology in education by instructors and is an important concept in both the support of and opposition to adaptive learning.

The first teaching machines.

Teaching machines are "a way to deliver instruction by using technology that marries content and pedagogy into a self-directed experience for a learner and which relies on minimal assistance from a live instructor" (Ferster, 2014, p. 17). They take methods to using technology in education to break up learning into segments and lead learners step by step, and at their own pace, toward understanding. Early teaching machines focused on the individual learner through one-on-one interactions and contributed directly to the first attempt at adaptive learning in 1960: the PLATO project.

Well before that project took shape, however, the first of the notable automated teaching machines was introduced by psychologist Sidney Pressey in 1927 (Ferster, 2014). He called it a "Machine for Intelligence Tests" (Waddington, 2018). Pressey's work stemmed from his experience with schoolchildren in rural Indiana where he was "struck with the tremendous variation in their academic abilities and how they were forced to progress together at a slow, lockstep pace that did not serve all students well" (Ferster, 2014, p.52). Pressey was the first in a long line of academics and researchers who laid the foundations of what we know as adaptive learning by first recognizing the need of the individual and focusing on the individual during the development of educational technology. Pressey's machine, resembling a large adding machine, was initially used as an automated testing tool that would show a question and only move on to the next question when the correct answer was presented (Anderson, 1925). In a later revision of his machine, Pressey designed a candy-dispensing attachment where a candy would be dispensed

from the front of the machine after a threshold of correct responses was reached (Waddington, 2018).

Much like a computer today can be used for multiple purposes, early teaching machines built for a particular purpose, or to address a certain issue, could serve multiple functions and support multiple approaches. Pressey's teaching machine was built as a testing tool but also supported both of what we now consider the individualization and personalization approaches to teaching and learning. Pressey saw testing "as the means to find out how to adapt instruction to meet learners where they were academically" (Ferster, 2014, p.52) through instructor-set learning outcomes, a component in individualization. However, learners setting their own testing pace is an element of personalization (Ferster, 2014). The designer of a technology has control over all aspects of a technology and the technology often reflects the ideals and beliefs of the individual or group that created it. Teaching machines were, and still are, heavily influenced by the theoretical foundations of their designers, which can be seen in the methods the technology takes to achieve its goal.

E.L. Thorndike, born in 1874, originated many of the concepts that now define behaviorism, such as the stimulus-response connection. Behaviorism is a foundational theory in the development of adaptive learning systems that "equates learning with changes in either the form or frequency of observable performance" (Ertmer & Newby, 1993, p.55). Learning occurs when the presentation of a specific stimulus results in a proper response and the reinforcement of a proper response means it is more likely to occur (Ertmer & Newby, 1993). Thorndike's *law of effect*, later called *reinforcement theory* by B. F. Skinner, posits that "if learners receive a satisfactory result for an action, it tends to strengthen the connection with a situation, whereas an unsatisfactory result tends to weaken the connection" (Ferster, 2014).

Additionally, Thorndike's *law of exercise*, which states that repetition supports remembering, formed the basis for the requirement to provide two correct answers in a row to understand how much practice was needed in Pressey's machine (Pressey, 1927). In 1912, Thorndike stated that "if, by a miracle of mechanical ingenuity, a book could be arranged that only to him who had done what was directed on page one would page two become visible, and so on, much that now requires personal instruction could be managed by print" (Thorndike, 1914), which was an insight into automated learning before it was fully possible.

Psychologist B.F. Skinner's initial work in *operant conditioning* in the 1930s formed the groundwork for his future contributions to educational technology and set a theoretical foundation for automated instruction for many years to come (Ferster, 2014). Based on Thorndike's law of effect, operant conditioning surmises that learning occurs when desired behaviors are systematically reinforced, such as providing immediate positive feedback for positive learner performance (McLeod, 2018). After observing his daughter's classroom and questioning the instructional approach in 1953, Skinner, who was initially unaware of Pressey's earlier work, set about creating a teaching machine based on his own work on operant conditioning. He proposed a machine based on *programming,* or *programmed instruction*, "where the student is led in a directed manner through the content by taking many small steps, each step requiring a response" (Ferster, 2014) and would receive immediate feedback, which would fill the role of the instructor. The learner would then be in control of the pace and would only move forward when the content was mastered, an example of personalization through a teaching machine. The series of small steps in programming, called *frames*, would build on what the learner already knew to lead them to the next frame (Ferster, 2014). This approach

demonstrates several key tenets of adaptive learning today, including the learner setting the pace, moving forward when content is mastered, and building on what the learner already knows.

Instructor roles: a question from the beginning.

The advent of increasingly learner-centered approaches in the 1960s and 1970s, facilitated by the rise in available educational technology, contributed to what some saw as "a dramatic evolution in faculty roles" (Beaudoin, 1990, p.21) and raised fundamental questions on how instructors would contribute to the teaching-learning process (Beaudoin, 1990). In a widely cited article from 1993 titled *From Sage on the Stage to Guide on the Side,* Alison King highlighted that the role of the instructor in individual-centered theory was to facilitate learning in "less directive ways"(King, 1993, p.30). While discussions on the changing role of the instructor have increased in recent years, it is important to note that the role of the instructor has been a consideration since the introduction of early learner-centered approaches and the eventual use of technology for individual instruction. Some, such as Pressey and Skinner, actively considered the role of the instructor, while others sought to bring about a change in traditional teaching methods in their approaches, such as the Keller Plan and Individually Prescribed Instruction (Keller, 1968; Lindvall & Bolvin, 1970).

Supplement or replace with technology: Pressey vs Skinner.

Pressey and Skinner had fundamental differences in how their machines fit into the educational environment. The "supplement or replace" argument over the role of technology, while still strong to this day, originated during the development of early teaching machines. Pressey envisioned his machine as supplemental to traditional instruction, to be used to support practice through individualism, and favored multiple choice questions for testing (Fry, 1960). Skinner, on the other hand, viewed his machine as replacing the instructor where instruction

came from the content creator, as opposed to the machine itself (Ferster, 2014). He, along with subsequent researchers, believed that success came from the design of the instructional materials rather than the machines, as the devices were simply a means to deliver the material to an individual learner. Skinner's teaching machine followed his preference for personalization by replacing the instructor and giving the learner more control over the content and pace. Although both devices were developed concurrently, Skinner's ideas attracted more attention and programmed instruction became the primary focus of research and the basis for teaching machines in the 1960s (Burton, Moore, & Magliaro, 2013). The widespread use of programmed instruction in an attempt to replace the instructor became known as the *automated instruction movement* (Carter, 1961).

The Keller Plan.

F. S. Keller, J. Gilmore Sherman, and two fellow psychologists at the University of Brasilia developed the Keller Plan in the 1960s (Keller, 1974). The Keller Plan, also known as *personalized system of instruction* (PSI), is "derived from the behaviorist reinforcement psychology with influence from teaching machines and programmed instruction" (Chen, 2009, p.162) and posited that learners would perform better if they found their work satisfying. The main features of PSI were "the unitizing of course content; self-pacing of the students through units, with mastery demanded at each step, but with repeated tests where necessary, at the hands of well-instructed student proctors, without penalty in the case of failure and with maximum credit when the job was done" (Keller, 1974, p. 4). PSI was unique in that it was developed for higher education and that it elevated the use of proctors, who were undergraduate students that had completed the course, to the traditional role of the instructor. In PSI, the instructor's lectures

and demonstrations were for enrichment and learner motivation, not for instructional purposes (Chen, 2009, p.162).

In a 1968 article called "Good-Bye, Teacher…" Keller called attention to the changing role of the instructor in individualized instruction (Keller, 1968). He stated that the instructor's "public appearances as classroom entertainer, expositor, critic, and debater no longer seem important" (Keller, 1968, p.88) and that the instructor then "becomes an educational engineer, a contingency manager, with the responsibility of serving the great majority, rather than the small minority, of young men and women who come to him for schooling in the area of his competence" (Keller, 1968, p.88). Keller's view of the instructor as a servant rather than a leader in education demonstrates early views of the changing role of the instructor through a focus on the individual.

Individually prescribed instruction.

Robert Glaser introduced Individually Prescribed Instruction (IPI) in 1962 as a synthesis of previous research into learner-specific instruction (I. Chen, 2009). IPI is a method of individualized instruction based on a structured curriculum in which assessments, teaching materials, and teaching methods were aligned (Scanlon, 1970). In essence, the learner is prescribed a set of learning objectives based on their goals and capabilities, and learning progress is monitored and evaluated based on their objectives. IPI is a learner-driven and paced method of personalized learning.

In 1970, C. M. Lindvall and John O. Bolvin posited that it would be possible to create a "computer assisted instruction system where all decisions were built into the system itself" (Lindvall & Bolvin, 1970, p. 37) based on IPI. At the time it was theorized, a system that could achieve IPI was not possible because "the desired type of individualized instruction requires a

program in which pupils can take part in meaningful learning activities adapted to their own requirements and to a considerable degree directed and managed by each individual student" (Lindvall & Bolvin, 1970, pp. 37–38). In essence, technology had not advanced to the point where offering IPI was possible. Such a system would fall under the category of adaptive learning today. Lindvall and Bolvin went on to state that the role of the instructor, should a computer-assisted instruction system be built, would be to make the system function, supplement the system, and provide achievement of goals that are only possible through instructor intervention (Lindvall & Bolvin, 1970). The role of the instructor would therefore be relegated to that of someone to maintain the system and fill in for the shortcomings of the system. Had it been possible for Lindvall and Bolvin to follow through with the development of the IPI computer-assisted instruction system, it would have been the first true adaptive learning system.

Programmed instruction to adaptation.

Proponents of programmed instruction were divided into two groups by the approach they believed in: *linear* or *branching.* B.F. Skinner, Fred Keller, and their disciples believed in the linear and *constructivist* approach where learners "followed one path through the material and generated the answer, as opposed to choosing from a list of multiple options" (Ferster, 2014, p. 87). Skinner and associates gave little to no credence to incorrect responses, believing that they contributed little to learning. Conversely, the branching approach was promoted by psychologist Norman Crowder and published in 1963. He believed that incorrect responses were an "opportunity to provide remedial instruction by routing students to different places in the instruction based on the kind of wrong answers they gave" (Ferster, 2014, p.87). Crowder's notion that a program could *adapt* to the learner's current level of knowledge and offer material

based on that current level of understanding provided one of the longstanding theoretical elements for instruction currently used in adaptive learning technology (Crowder, 1963).

Success in early teaching machines and programmed instruction was short-lived. Despite research and evidence suggesting the effectiveness of early teaching machines and programmed instruction in the 1950s and 1960s, schools failed to adopt them in any significant quantity (Ferster, 2014). Three main issues hindered adoption: (1) the devices and approach did not work for all content material—they only worked successfully in rigid and predictable areas such as mathematics; (2) school systems pushed back due to budget constraints (which limited the ability to purchase the systems) and negative instructor perception of teacher-proofing; and (3) schools were not equipped to deal with students who did not learn in "age-progressed groups" (Ferster, 2014, p. 90). The theoretical foundations and findings from early teaching machines would find use in a new medium to continue to progress: computers.

PLATO

The Programmed Logic for Automated Teaching Operations (PLATO) project at the University of Illinois in 1960 was the first successful use of a computer in education and the first meeting of education, technology, and personalization(Ferster, 2014), making the PLATO project the first true instance of an adaptive learning initiative. The theories and elements of adaptive learning that developed until this point existed in their own environments until they all came together at the University of Illinois. Brian Dear delivered insights into the origin and development of PLATO in his 2017 book *The Friendly Orange Glow: The Untold Story of the PLATO System and the Dawn of Cyberculture* (Dear, 2017). Dear's book is central to understanding how various concepts about adaptive learning today were first introduced and

developed from the PLATO project and how the project ties into earlier educational technology insights.

The PLATO project began at the Control Systems Laboratory (CSL), a classified military research lab at the University of Illinois in Urbana-Champaign (Dear, 2017). During World War II, top university instructors around the country were recruited for the war effort, working on military projects such as the Manhattan Project and the radar project at the MIT Radiation Lab. Many scientists and engineers left the University of Illinois to join the war effort and chose not to return to the university. When the Korean War started in 1950, the University of Illinois created CSL to undertake war effort projects and appeal to scientists and engineers and keep them from leaving. Lab funding came from Army, Navy, and Air Force grants to work on "projects that it thought were important for the Defense Department" (Dear, 2017, p.31).

In 1952, computers were very large and very expensive. The University of Illinois, having designed and built a computer for the military, received funding from the military to build a computer of its own named the Illinois Automatic Computer, or ILLIAC. Dan Alpert, a well-respected physicist, was appointed director of CSL in 1959. After the end of the Korean War, CSL was struggling to find its place. Alpert proposed a plan to keep the lab in operation, declassify the lab, and establish new projects. The outcome of that plan was that the Control Systems Laboratory was declassified and renamed the Coordinated Science Lab, keeping the CSL acronym.

Tasked with identifying and undertaking new projects, Alpert was intrigued with the idea of CSL physicist Chalmers Sherwin for the use of ILLIAC in education, and so set out to use computers to advance the university's educational mission (Dear, 2017). Sherwin had proposed the idea of a computerized "book with feedback" (Dear, 2017, p.37) based on the works of

Thorndike, Skinner, and Crowder, and that is the direction in which the lab moved. They needed a project leader and so in 1960 Alpert invited Don Blitzer, an engineer, to take the lead of the CSL project. Its purpose was to build "a computer that could teach" (Dear, 2017, p. 49), later to be called PLATO. Blitzer was the visionary that PLATO needed and his guidance led the development of PLATO until its eventual decline in the 1980s. Alpert's proposal to Engineering School dean William Everitt read:

> As suggested by Professor Sherwin some time ago, the advent of the high speed computer makes possible a new approach to education in which the principle of feedback (from the student) may be applied to such traditional educational tools as the book, visual aids, etc. While this idea is in principle applicable to the teaching research objective of any course of study at various levels of sophistication, the first research objective will be towards the design of an 'automatic teaching machine' to teach students at various levels how to use a high speed computer. This particular objective is especially suited to the talent and motivation of the people who would have to design such a machine and represents a unique educational need in the coming decade. (Dear, 2017, p. 54)

CSL's task included not only the design of the machine, but also the programming language, teaching objectives, philosophical approaches, effectiveness, and any other related components of building the teaching machine (Dear, 2017).

The PLATO system was true to Thorndike's vision of a machine capable of arranging instruction so that only after mastery of page one was completed would page two become visible to the learner. It also moved beyond what Thorndike and Skinner envisioned: PLATO was able to achieve *answer judging*, which is "the ability of the computer to not only evaluate the input of the student, but also figure out its meaning, and not only determine if it was correct or not, but

also figure out if it was partially correct or partially incorrect, and provide the most meaningful feedback to the student no matter what had been the input" (Dear, 2017, p.64). With answer judging, Crowder's notion that a program could adapt to a learner's current level of knowledge was now possible. In this way, Skinner and Crowder's work directly influenced PLATO's approach.

Because computers in the 1960s were large and very expensive, each learner was not able to personally own one. Instead, PLATO was designed using terminals connected via a communications connection to a central computer, similar to what is now called *cloud-computing* (Dear, 2017). With the processing power centralized in ILLIAC, each terminal relied on a time-sharing model where each terminal was slotted a fraction of processing time and every terminal relied on ILLIAC's availability. The terminal structure would later be replaced by the personal computer in the 1980s. PLATO also collected learner data that was used while students worked on lessons and later made available to instructors in what is now called *analytics*. Analytics are a major driver in decision-making across many industries and a foundational element of adaptive learning today.

Six years after Skinner introduced his teaching machine in 1954, the PLATO project was off and running (Dear, 2017). In the three years after it started, PLATO progressed from PLATO I to PLATO II then on to PLATO III, with minor improvements through each subsequent version. CSL's search for cost savings after the creation of PLATO III led to the development of two technologies that would be thirty years ahead of their time: the flat panel display and touch sensitivity in displays. Their search for a cheaper alternative to the bulky, challenging, and expensive cathode ray tube (CRT) displays led to the development of the flat plasma display in 1964, which would display in a "friendly orange glow" (Dear, 2017, p.111).

The plasma display was then overlaid with a touch-sensitive grid and added to the PLATO IV terminal by its launch in 1972. While there were a few more improvements to the hardware over time, the PLATO IV terminal was the pinnacle of the project's teaching machine hardware.

A notable difference in PLATO's design, versus another competing project in development at the same time, was that the project's hardware advancements were guided by content and instructor needs. Don Blitzer's approach for the hardware was "give me the tasks you want to do, and let's design hardware broad enough to take care of all of it" (Dear, 2017, p.116). The System for Organizing Content to Review and Teach Educational Subjects (SOCRATES) project, led by fellow CSL psychology professor Larry Stolurow, was a competing system based on theories from psychology and education (Dear, 2017). Stolurow's approach was "give me the hardware to do the task I want to do" (Dear, 2017, p.116). Therefore, the SOCRATES project hardware was built to follow a rigid approach where the content was forced to follow the theories the hardware was built for. PLATO's design offered flexibility in both content and theoretical approach, so authors were free to create their own lessons as they saw fit. Ultimately, SOCRATES fell out of favor and PLATO continued on as CSL's only teaching machine. In 1966 the PLATO project was shifted from CSL to the newly formed Computer-based Education Research Lab (CERL) to continue its work, with Don Blitzer still leading the project.

The content freedom that PLATO provided for authors enabled the creation of numerous lessons on a wide range of subjects. Instructors were "invited, encouraged, to design their own lessons for their students, however they wished" (Dear, 2017, p.175). Making full use of the graphic displays and an easy programming language named TUTOR, instructors created lessons such as: Darts, which taught fractions by throwing darts at a balloon on a vertical number line,

entering the location as a fraction; Sentences, to teach elementary reading by touching words on a screen to create a sentence, which was then evaluated by PLATO; Titrate, a chemistry lesson that simulated titration, or the gradual addition of one chemical into another until a reaction or neutralization occurred; and a biology lesson in the genetics of fruit flies that simulated breeding fruit flies with various traits (Dear, 2017). Lessons created in PLATO utilized immediate feedback and answer judging as a standard offering of using the hardware.

At its peak, CERL had over 1,500 PLATO terminals in operation, and had attracted a great deal of attention from governments, educational institutions, and businesses. Seeing the potential market, the Control Data Corporation (CDC) purchased the PLATO license rights and trademark in 1976 from the University of Illinois after years of talks (Dear, 2017). PLATO continued to develop at CDC, but after the shift to a for-profit mentality and the eventual departure of Don Blitzer, PLATO was shut down in 1986 (Dear, 2017). The PLATO project either developed or was an early example of technologies now commonly associated with the computer age, such as plasma displays, the touchscreen, online chat, online gaming, word processing software, cloud computing, and social networks. PLATO was proof that adaptive learning is possible through the combination of education, technology, and personalization.

Computer-Aided Instruction

By the mid-1960s, the failure of analog teaching machines, such as Skinner's teaching machine, in the automated instruction movement became apparent, but the idea lived on in computers (Waddington, 2018). The term "teaching machine" was replaced by *computer-aided instruction* (CAI) to represent new work to automate instruction using computers, such as in PLATO (Waddington, 2018), but the concept was not significantly different. The theoretical foundations of early teaching machines that were rooted in behaviorism gave way to more

complex interactions between multiple theories in CAI. This was due to a steep decline in the popularity of behaviorism and its impact on learning in the 1970s, which led to a rise in educational theories from cognitive psychology known as cognitivism (Waddington, 2018). Both behaviorism and cognitivism concentrate on the individual learner and personalization, but in different ways. Behaviorism focuses on learner response and reinforcement, while cognitivism "focuses on the mental activities of the learner that *lead up* to a response and acknowledges the processes of mental planning, goal-setting, and organizational strategies" (Ertmer & Newby, 1993, p.59). Cognitivism in CAI was more innovative, with far more theoretical frameworks and strategies, than behaviorism (Waddington, 2018). In the evolution of adaptive learning, learner responses and repetition became less important and an immersive, computer-controlled environment targeted on the processing of information developed through cognitivism (Waddington, 2018). The PLATO project was an example of how complex CAI could be used to demonstrate simple adaptive learning in an immersive, touch-enabled, personalized computer environment.

Rise of the Personal Computer

In 1960, when the PLATO project first began, computers required a dedicated room and only a handful of education institutions had the funding to purchase them. While other educational technologies advanced in subsequent years, such as the Scantron machine and the hand-held graphing calculator, few technologies changed education as profoundly as the personal computer (PC). The advent of the PC in the late 1970s ushered in a time of rapid change in society and education and is the most important technological development affecting adaptive learning to date.

The first personal computers were developed by amateur computer hobbyists rather than those with access to the larger systems, such as governments, large manufacturers, or research institutions (Abbate, 1999). The Altair 8800, developed by a small company called Micro Instrumentation Telemetry Systems in 1975, was the first in a long line of PCs (Abbate, 1999). Although the Altair 8800 was available for anyone to purchase, the introduction and mass marketing of the Apple II in 1977 kicked off the PC movement that would introduce computers to locations and industries worldwide (Abbate, 1999). In 1981, after seeing small companies like Apple make huge profits, IBM released the IBM PC (Abbate, 1999). The IBM PC used an "open" architecture instead of using proprietary technology, meaning that other companies could clone the PC (Abbate, 1999). The IBM name and the open architecture established the PC as the industry standard, dominating the hardware market for many years.

PCs would not have achieved dominance with their hardware alone; software and graphical user interfaces (GUIs) drove the ability of PCs to proliferate across many industries and at home. GUIs allow users to interact with computers using icons or other visual indicators rather than learning code and interacting via the text-based command line. The use of GUIs and software innovations from the 1960s, such as the GUI and learning software designed for PLATO, made the PC truly user-friendly by removing the need to know code to use the computer and by offering necessary tools such as word processing and spreadsheets (Abbate, 1999). Pictures, icons, and plain text in operating systems became the standard way to interact with the PC. Bill Gates and Paul Allen started the Microsoft Company in 1975 to sell programming language software, which later evolved into the Microsoft Windows GUI operating system (Abbate, 1999). By the late 1980s, most PCs were running either Apple's Macintosh GUI operating system or Microsoft Windows. With the addition of input devices, such as the

computer mouse, PCs became user-friendly, affordable, and indispensable for many people and businesses. The PC made it so that the individual had access to a computer at home, business, and school.

Personal computers in education.

The PC was adaptable, effective, and efficient in its application across many fields, including education. The proliferation of computers in education was due, in large part, to the intervention of the federal government and ongoing improvements in hardware affordability. As a result of the *Ronald Reagan's National Commission on Excellence in Education Report* in 1983, funding for classroom computers became available across the U.S. (Ferster, 2014). The availability of funding and the rise of the affordable and user-friendly PC in the 1980s meant that computers were no longer limited to an elite few. Schools started purchasing PCs for instructors to use in the classroom, and by the late 1980s personal computers were present throughout higher education and K-12 schools.

With computers readily available for researchers, instructors, and learners, the uses of a PC in education expanded quickly. Although the individual uses for a PC in education were almost limitless, three categories for how the PC was used in education stood out. Educator and education computing pioneer Robert Taylor identified these three principal way in which computers were used, or could be used, in early classrooms: as a *tool*, computers supported student performance in unrelated learning goals; as a *tutee,* the computer is the subject of programming or instruction by learners; and as a *tutor*, computers operated like the traditional teaching machines, delivering programmed content (Taylor, 2003).

As a tool, computer instruction is incidental, such as using the calculator or word processing software on a computer. The instructor does not actively use it for teaching and the

learner only uses the software as it was intended, often relying on some pre-knowledge such as knowing how to use a calculator or knowing how to write (Taylor, 2003). The computer used as a tool can benefit education by improving or enriching learning, but it does not significantly contribute to the advancement of education.

As a tutee, the computer becomes the subject of instruction by the learner—the learner teaches the computer. The learner must first learn how to program, or "talk" to the computer before they can learn what they are trying to teach the computer because "you can't teach what you don't understand" (Taylor, 2003, p.245). The benefits to this use of computers are:

> Learners gain new insights into their own thinking through learning to program, and teachers have their understanding of education enriched and broadened as they see how their students can benefit from treating the computer as a tutee. As a result, extended use of the computer as tutee can shift the focus of education in the classroom from end product to process, from acquiring facts to manipulating and understanding them (Taylor, 2003, p.245).

Seymour Papert, a mathematician, computer scientist, and educator, was a strong promoter of the PC as a tutee in education. Papert "wanted to provide students with a simplified environment that required them to authentically learn the same content while in pursuit of solving problems" (Ferster, 2014, p.103), using computers as teaching machines. In Papert's view of constructionism, which posits that learners build knowledge structures as they are situated in an environment, the role of the instructor is to "define a problem that encompasses the content to be learned, construct an environment that will facilitate solving the problem through exploration and inquiry, and provide gentle support for the student's exploration of that

environment" (Ferster, 2014, p.105). Papert put the student in control of the learning process, which is a central idea in personalization and adaptive learning.

As a tutor, the computer is programmed by an expert in a particular subject to instruct the learner or group of leaners (Taylor, 2003). This use of computers as a tutor is also referred to as CAI (Taylor, 2003). The computer as a tutor was the goal of the automated instructor movement and the ultimate teaching machine. In 1980, Robert Taylor described using the computer as a tutor by stating:

> The computer presents some subject material, the student responds, the computer evaluates the response, and, from the results of the evaluation, determines what to present next. At its best, the computer tutor keeps complete records on each student being tutored; it has at its disposal a wide range of subject detail it can present; and it has an extensive and flexible way to test and then lead the student through the material. With appropriately well-designed software, the computer tutor can easily and swiftly tailor its presentation to accommodate a wide range of student differences (Taylor, 2003, p.243).

This approach to using a computer in education represents a significant step in the historical development of adaptive learning. Adaptive learning advanced from the idea of individualized learning in the first teaching machines, to frameworks based on behaviorism and cognitivism, then demonstrated in a small scale with the PLATO project, to now being closer to the definition of adaptive learning today via the use of PCs as tutors in education. Additionally, Taylor directly addressed how the computer as a tutor promotes personalization when he stated that "human instruction rarely aims to accommodate individual differences because the normal classroom situation prohibits such accommodation... because such accommodation is possible

with the computer as tutor, the substantive and strategic details needed to individualize the lesson tend to get included" (Taylor, 2003, p.244).

The use of the computer as a tutor would not be possible without the work of several pioneers in the use of computers in education, including Alfred Bork and Patrick Suppes. Alfred Bork was a physics professor and founder/director of the Educational Technology Center at the University of California Irvine from 1968 to 1994. Bork's interests were in the application of computing to physics instruction and saw the personal computer as "the major vehicle in a new generation of computer-assisted learning" (Taylor, 2003, p.246). Patrick Suppes was a philosophy and mathematics professor at Stanford University for 64 years, after joining the philosophy department in 1950 (Markoff, 2014). In 1967 Suppes founded the Computer Curriculum Corporation (CCC) through a partnership with IBM, which was credited as the first company to pursue interactive CAI in the classroom (Niemiec & Walberg, 1989). Both Bork's and Suppes' work in using CAI exemplified the use of computers as a tutor. Taylor summarized their work as follow:

> Bork has concentrated much of his thinking on how best to develop good tutor material for physics instruction, while Suppes has developed material for a wide range of subjects. Both have used the computer to store, analyze, and act upon student results, and both have used such sophisticated peripheral devices as audio or graphics to maintain student involvement and enrich the nature of the tutoring (Taylor, 2003, p.249).

CAI grew quickly in the 1960s, when federal funding for research and development in education was implemented. In 1969, new developments in CAI formed the next iteration of adaptive learning: Intelligent Tutoring Systems (Ferster, 2014).

Intelligent Tutoring Systems

Between 1969 and the mid-1990s, CAI sprouted a new form of computers as tutors that used intelligent means of instruction to create a truly personalized experience for learners called *intelligent tutoring systems* (ITS) (Ferster, 2014). ITS differed from CAI in that "rather than the one-size-fits-all strategy of delivering content to a passive learner, ITS designs are able to customize the learning experience the student receives based on factors such as preexisting knowledge, learning style, and the student's progress through the content material" (Ferster, 2014, pp.115-116). The first ITS was developed by Jamie Carbonell in 1969. Aided by personal computers in education, ITS continued to develop through the mid-1990s when the internet and the knowledge economy reshaped the educational technology landscape (Ferster, 2014; Slaughter & Rhoades, 2004).

The development of intelligent teaching machines and software stemmed from the philosophical and technological framework that researchers developed in the field of *artificial intelligence* in the 1960s and 1970s. In the context of education, "a system must *behave* intelligently, not actually *be* intelligent, like a human" (Ferster, 2014, p.114) to be defined as an intelligent tool. Papert defined artificial intelligence as "extending the capacity of machines to perform functions that would be intelligent if performed by people" (Papert, 1980, p.157). Some intelligent teaching machines use artificial intelligence applied to traditional computer-aided instruction technologies in an attempt to mimic human tutors.

Intelligent tutoring systems are closer to our current definition of adaptive learning than the PLATO project. The basic organizational structure of most ITS include a number of conceptual models that interact with each other: the *content model* "contains a web-like mapping of the content to be learned, defining the prerequisites and dependencies between content

elements" (Ferster, 2014, p.116); the *student model* "is unique to each learner and works in parallel with the content model to record what the student does and does not understand" (Ferster, 2014, p.116); and the *pedagogical model* is "the method of delivering instruction to the learner" (Ferster, 2014, p.116).

ITS start the instruction process through assessment to determine what the learner already knows. They then continuously update the student model, or the individual learner record, as the learner acquires the presented knowledge. Pedagogically-appropriate material is presented as the learner progresses based on a comparison of the student model and content model (Ferster, 2014).

With this early historical context as background, the following chapter progresses to a discussion of adaptive learning in the current knowledge economy. Together with the early concepts presented in this chapter, the final chapter then builds on this to discuss the drivers and criticisms of the use of adaptive learning today. Finally, it moves to predictions about how this movement may continue to evolve in the future.

CHAPTER 3

Adaptive Learning in the Knowledge Economy

Adaptive learning benefited greatly from the rise of the knowledge economy and academic capitalism from the mid-1980s and on. Ties between higher education, governments, and the market during this time accelerated the development of technologies directly associated with how we now define adaptive learning, such as online learning and learning management systems. This chapter highlights the concepts and technologies on which adaptive learning has built on. It also provides examples of the first adaptive learning projects in the knowledge economy and how academic capitalism fostered their development.

Rise of the Knowledge Economy

The knowledge economy is marked by the period where knowledge-intensive activities led to an accelerated pace of advancements in science and technology, generally accepted as beginning in the early 1980s (Powell & Snellman, 2004; Slaughter, 2014; Slaughter & Rhoades, 2004). Historically, the beginning of this period had been difficult to gauge, as finding a metric to establish when society shifted to be more dependent on knowledge production was difficult (Powell & Snellman, 2004). Through the work of many researchers, patents were identified as a key indicator of intellectual capital and economically valuable knowledge (Powell & Snellman, 2004). Powell and Snellman (2004) plotted out U.S. patenting activity between 1963 and 2001 and found a trend in patents which suggested an acceleration in the production of new knowledge. They found that:

> The 20-year period between 1963 and 1983 evinces no strong trend. There is a rise in the late 1960s, but a decline in the 1970s that eventually drops below 1963 levels in 1979. Around 1983, the volume of patenting picks up and increases steadily until the late

1990s, when the pace takes off even more sharply. Over this 20-year period, the number of patents issued to U.S. inventors more than doubles, while all patents issued in the United States climb from less than 47,642 to more than 168,040 (Powell & Snellman, 2004, p. 202).

Slaughter and Rhoades (2004) also point to roughly the same timeline as the start of the new economy and explain that colleges and universities were key participants in the patenting trend. They state that "prior to 1981, fewer than 250 patents were issued to universities per year" (2004, p. 17) and that in 1999 alone, colleges and universities filed 5,545 patent applications (Slaughter & Rhoades, 2004). Additionally, they note that "in 1978, several universities permitted acquisition of equity in companies licensing their technology; by 2000, 70 percent of a sample of sixty-seven research universities had participated in at least one equity deal" (Slaughter & Rhoades, 2004, p. 17). The increased participation of colleges and universities in patent-producing endeavors and equity acquisitions during this time marks the rise of the academic capitalist knowledge/learning regime over the public-good knowledge/learning regime where privatizing knowledge and market-like endeavors grew within higher education.

Globalization and academic capitalism.

The knowledge economy sparked a technological revolution in communications and transport that opened geographical boundaries to the point where distance and time did not matter (Nayyar, 2008). Coupled with market forces driving competition and profit, the knowledge economy gave rise to a worldwide economic change called *globalization* in the 1980s (Nayyar, 2008; Slaughter & Leslie, 1997). Globalization is a set of processes that include cross-border flows of capital, people, and ideas in an interdependence that has transformed political, social, cultural, and economic relations around the world (Kauppinen & Cantwell, 2014).

The globalization movement unbound entire industries that were normally restricted by distance and time to communicate and interact at a global scale, including higher education. Globalization had four main implications for higher education.

> First is the constriction of monies available for discretionary activities such as postsecondary education. Second is the growing centrality of techno science and fields closely involved with markets, particularly international markets. Third is the tightening relationships between multinational corporations and state agencies concerned with product development and innovation. Fourth is the increased focus of multinationals and established industrial countries on global intellectual property strategies (Slaughter & Leslie, 1997, pp. 38–39).

Higher education's responses to these implications led to academic capitalism. In the 1980s and 1990s the United States pursued supply-side economic policies that shifted public resources from social programs to economic development efforts (Slaughter & Leslie, 1997). Combined with national policies to reduce debts that increase entitlements, less national and state public money was available for higher education and any new money was concentrated on the advancement of technology and science. In essence, postsecondary education was "directed toward national 'wealth creation' and away from traditional concern with the liberal education of undergraduates" (Slaughter & Leslie, 1997, p. 37), one of the main points of academic capitalism. With higher education at the forefront of technology and science, whether through research and development, education, or training, it became more important to the market. The relationships between higher education, the market, and government tightened through globalization, further advancing economic capitalism during this time. Lastly, "leaders of corporations, government, and tertiary institutions increasingly see faculty work as possible

intellectual property, more valuable in global markets as product or commodity than as unremunerated contribution to an international community of scholars" (Slaughter & Leslie, 1997, p. 39). Universities became a source for corporations and governments to seek innovations that would produce intellectual property, which is considered the privatization of knowledge. Globalization changed the way higher education interacted with the world, breaking down the silo of the "ivory tower" and opening up higher education to further ties with governments and the market (Ward, 2008).

Neoliberalism.

Changes in higher education as responses to the knowledge economy and globalization were not imposed on higher education by force. Instead, higher education responded to these economic factors from within by making administrative changes that were influenced by these external factors. Academic capitalism is a result of a changing ideology in administrative decision making called neoliberalism (Slaughter & Rhoades, 2004). Neoliberalism is a shift in ideology away from state social welfare and toward strong individual private property rights, free markets, and free trade (Thorsen, 2010). The rise of neoliberalism in the 1980s and 1990s helped replace the higher education culture of open intellectual inquiry with institutional priorities on performance, performance indicators, quality assurance metrics, and academic audits (Baltodano, 2012; Olssen & Peters, 2005). In higher education, neoliberal ideology is characterized by institutions moving toward market and market-like behaviors, making institutions enterprising and competitive in the market and between each other—in other words, academic capitalism (Olssen & Peters, 2005; Slaughter & Rhoades, 2000, 2004). In neoliberalism, "the fundamental social roles of public higher education, including providing

increased upward mobility for underserved populations, have been displaced by the economic role of serving corporations' global competitiveness" (Slaughter & Rhoades, 2000, p. 73).

Neoliberal ideology led to academic capitalism, which in turn created an environment where adaptive learning could grow into a far-reaching movement. Higher education administrators holding neoliberal values drove institutions to want to compete for resources beyond the state and local areas, which were the traditional target markets for most higher education institutions. Some higher education institutions turned to adaptive learning as a way to accomplish this. Adaptive leaning, as a far-reaching educational technology, holds the possibility of providing a competitive advantage by way of cost savings, increased accessibility, and better education quality in the global knowledge economy. It was in part through the influence of neoliberalism in higher education that adaptive learning developed as a form of educational technology, with governments and market actors throughout the history of adaptive learning supporting its development.

The changing role of higher education in the knowledge economy.

As alluded to earlier, the knowledge economy exerted tremendous pressure on universities around the world to change their activities and roles within the global economy (Ward, 2008). Research innovations and advanced technical and professional programs offered by universities are now viewed as key resources in the global knowledge economy, even to the point that "universities long viewed as 'ivory towers' are increasingly recognized as 'oil wells' of the new economy" (Ward, 2008, p. 259). The shifting of public monies, the growing importance of higher education in technology and science, and the building relationships between higher education, the market, and government all pressured higher education to become the supplier of well-educated people into the workforce (Powell & Snellman, 2004; Slaughter,

2014; Slaughter & Rhoades, 2004; Ward, 2008). This change from the traditional concern for the liberal education of undergraduates demonstrates the changing role of higher education in the knowledge economy. The World Bank, a leader in the development of global economies, highlighted the need to transform education because "traditional educational systems, in which the teacher is the sole source of knowledge, are ill suited to equip people to work and live in a knowledge economy" (World Bank - IBRD, 2003, p. 28).

The knowledge economy sparked a transition from mass production to non-Fordist manufacturing, a model of manufacturing that relies on technology and a small, flexible, educated workforce comprised of part-time or contingent workers (Slaughter & Rhoades, 2004). The success of the U.S. economy and some international economies relied on corporations having well-educated workers in areas such as science, engineering, medicine, and law to create and protect processes, products, and services based on knowledge (Nayyar, 2008; Slaughter & Rhoades, 2004). Adaptive learning makes mass education possible and efficient, while still maintaining the personalized approach, to create the necessary workforce for the knowledge economy. Adaptive learning grew because there was a need, primarily for workforce development, and because technology in education matured enough to make it possible between the 1980s and the start of the adaptive learning movement in the early 2010s.

Importance of higher education to the knowledge economy.

The importance of higher education in the knowledge economy rests not only on its role in the development of an educated workforce; it is a critical part of the other three foundational elements that support a knowledge economy as well (World Bank - IBRD, 2003). The World Bank lists the following four pillars in a methodological framework that outlines the readiness or receptiveness of a country to sustain a knowledge economy:

1. A supportive economic and institutional regime to provide incentives for the efficient use of existing and new knowledge and the flourishing of entrepreneurship;
2. An educated and skilled population to create, share, and use knowledge;
3. A dynamic information infrastructure to facilitate the effective communication, dissemination, and processing of information;
4. An efficient innovation system of firms, research centers, universities, consultants, and other organizations to tap into the growing stock of global knowledge, assimilate and adapt it to local needs, and create new technology (World Bank - IBRD, 2003, p. 2).

The United States is listed as one of the top countries that have made investments and reforms in support of each of the four pillars, particularly through the opportunities for employment and innovation offered in the U.S. university system, and has seen great economic growth in the knowledge economy (Aubert, 2005). "The science-based technological innovation and industrial application that are the products of academic research are widely held to have been requisite to the trajectory of economic development that led the United States in the second half of the twentieth century to become a pre-dominant superpower" (Crow & Dabars, 2015, p. 22). Higher education institutions provide the necessary training for the ever-increasing number of professionals employed by corporations to invent, maintain, and innovate sophisticated technologies and products (Slaughter & Leslie, 1997). This work supports the second pillar—an educated and skilled workforce—and the fourth pillar—an efficient innovation system. Additionally, universities have become the sites where new technologies and products are developed, often in partnership with businesses and corporations (Park, 2011; Slaughter & Leslie, 1997).

Decreased state funding since 2001 helped spark the rise of the entrepreneurial university, wherein higher education institutions seek partnerships and market endeavors to sustain operations in the face of decreased government support (Pew Charitable Trusts, 2015; Slaughter, 2014; Slaughter & Leslie, 1997). Government support and incentives for these partnerships have grown as a way to offset criticism for cutting funding to higher education institutions, supporting the first pillar—a supportive regime. Lastly, higher education researchers see themselves as belonging to discipline-based communities that communicate, disseminate, and process information within their fields. There is also a commitment to community service from higher education in terms of "providing training and research, investigation and advice, as well as such services as consultancies, technology transfer, lifelong learning and continuing education" (Jongbloed, Enders, & Salerno, 2008, p. 312). Involvement in discipline-based communities and the participation of higher education and community service support the third pillar—dynamic information infrastructure—of the knowledge economy. In all, higher education has been critically important in the introduction and continuing development of the knowledge economy.

Essential Projects and Innovations

As the knowledge economy advanced, it supported the development and proliferation of projects and innovations that now serve as foundational elements for adaptive learning today. Beginning with the Andrew project and Project Athena in 1982, these project and innovations, which were notably influenced by academic capitalism, set the stage for the development of adaptive learning. They did this by either developing technologies which are now critical components of adaptive learning, such as learning management systems, establishing an environment which did not question the use of adaptive learning, such as the proliferation of

online learning, or trivialized the use of what would have been a radical way of conducting teaching and learning had the concept not been introduced slowly, such as the Open Learning Initiative. Continuing with the historical development of adaptive learning, the following sections provide more details on these projects and innovations that advanced because of the knowledge economy and academic capitalism.

The Andrew Project and Project Athena.

Many of the early advancements of computer technologies in higher education owe their start to the Andrew Project at Carnegie Mellon University (CMU) and Project Athena at MIT. These two projects advanced educational technologies in areas such as message boards and learning systems, but the advancements were only possible through academic capitalism. Without connections to the technology business market, these two higher education institutions would have been hard-pressed to undertake such initiatives on their own.

The Andrew Project was a joint venture between IBM and CMU that began in 1982 (Balkovich, Lerman, & Parmelee, 1985). The goal of the project was to design a university computing environment with a special emphasis on the needs of students and faculty in the academic setting (Borenstein, 1996). While the project did develop tools that were seen as prerequisites for the future support of educational technologies, its greatest significance lies in the method by which it was accomplished, which served as an example for future ties between higher education and the market. The ties between IBM and CMU were initially guided by the prospect of money towards research for CMU and technology transfers for IBM, but only CMU ended up achieving its prospect (Borenstein, 1996). Ultimately, for CMU "the development of the system didn't cost CMU much money, and served to bring in money, machines, and people

from IBM" (Borenstein, 1996, p. 10). For IBM, the connection with CMU "helped to enhance IBM's reputation within the university, research, and Unix communities" (1996, p. 10).

Project Athena was "an experiment to explore the potential uses of advanced computer technology in the university curriculum" (Balkovich et al., 1985, p. 112). The project was modeled after the Andrew Project, including its ties with technology corporations for funding and support (Balkovich et al., 1985). It was introduced in 1983 by MIT and was sponsored by IBM and Digital Equipment Corporation, one of the leading vendors of computer equipment at the time. Project Athena focused the use of computers in several areas of higher education, including as a tutor, as the textbook, as a blackboard, as a special purpose learning environment, and as a communications medium. The project officially ended in 1991, but not before it made significant advances in education technology, such as those described in the excerpt below (Cheung, Chow, Li, Koontz, & Self, 1999).

> Overall, 125 educational projects were funded during the course of Project Athena. Some of the more successful projects included the Athena Writing Project and the Aeronautical and Astronomical Engineering simulations. The purpose of the Athena Writing Project was to develop an integrated classroom system for teaching courses in scientific and expository writing. This electronic on-line system included computerized tools for editing and annotating papers, presenting class-work, and filing elements of course writing assignments (Cheung et al., 1999, p. 11).

Today, Project Athena is known for its contributions to the field of technology in distributed computing, or the interconnectivity of computers and other devices, instant messaging, and file servers (Arfman & Roden, 1992; Press, 1994). Toward the development of educational technologies, Project Athena introduced the feature of online consulting where a learner can ask

for assistance via the network and the online teaching assistant, which provided "students with direct access to the teaching assistants for the courses in which they are enrolled" (Arfman & Roden, 1992, p. 556). Additionally, Project Athena is credited as establishing the basic principles of Learning Management Systems through its use of interconnectivity, a central learning source, and online learning in higher education (Chaubey & Bhattacharya, 2015).

Online learning.

The introduction of the internet in 1982 and the proliferation of personal computers led to radical changes in education (Ferster, 2014). Concepts and ideas that existed in restricted applications prior to the 1980s, such as the PLATO project, benefited extensively from the introduction of the large-scale communications network. The internet helped create opportunities for an education free from the restrictions of time and space presented by learning at physical educational institutions.

Online learning is the evolution of distance learning through the use of the internet. Distance learning, also referred to as distance education, is an umbrella term that describes the delivery of educational content by a variety of methods where the source of the information and the learner do not share the same physical setting or perhaps the same time (Delen & Liew, 2016). Distance learning is historically rooted in early correspondence courses where the learner received educational content through the postal service (Ferster, 2014).

At the time of the rise of the knowledge economy, distance learning was heavily influenced by the spread of personal computers, the internet, and other technologies used for learning such as the CD-ROM. By the late 1980s and 1990s, distance education had become linked with advancements in communications methods such as "print materials, broadcast radio, broadcast television, computer conferencing, electronic mail, interactive video, satellite

telecommunications and multimedia computer technology"(McIsaac & Blocher, 1998, p. 43). The proliferation of the internet in the 1990s paved the way for the development of web-based learning technologies (Ferster, 2014), and the internet quickly became the primary mode of delivery for distance learning. Distance learning that relies primarily on the internet as a means of content delivery and communications has come to be known as *online learning* (Moore, Dickson-Deane, & Galyen, 2011). Today, online learning is the primary conveyance method for adaptive learning.

Online learning separates the learner from the physical institution of learning, allowing learners to access instructional material from any device that can access the internet. A learner can participate in learning in three ways: in person, completely online, or some combination of the two in what is known as *blended learning* (Ferster, 2014). In-person learning has the learner participating in the same physical location as the instructor, while completely online learning has the learner only participate in a learning experience via online learning methods. Blended learning is some combination of in-person learning and online learning during one learning experience, course, etc. The learning participation flexibility offered by online learning "makes it easy for a wider range of students to participate, including people who work during traditional school hours, stay at home parents, those with physical disabilities, and people in geographically remote locations" (Ferster, 2014, p. 124). A key advantage of online learning systems is "their ability to provide access for nontraditional students who are unable to attend classes in person because of work, family, or geography" (Ferster, 2014, p.124).

Online learning also has two distinct delivery methods. *Asynchronous* courses allow the learner to view the material when it is most convenient to them, while *synchronous* courses are typically lectures or presentations that occur at a set time with both the instructor and learners

present (Ferster, 2014). As a form of online learning, learners can participate in adaptive learning in the same way. Completely online adaptive learning allows the learner to be anywhere they have access to the internet. Blended learning with adaptive learning is a blend of the student attending a physical class for part of the time and using an adaptive learning system to supplement in-person learning. Adaptive learning, as a learner-centered approach, is offered asynchronously so that the learner can adopt their own pace.

Online learning systems are particularly appealing to educational institutions due to their ability to scale. In-person and synchronous courses are expensive to deliver because the instructor must be present to teach the learners each time. Online asynchronous courses can easily scale up, accommodating as many students as necessary, and the student decides when to complete the course. The instructors, or authors, need to only create the content once and it can be delivered via the internet at any time to anyone.

Learning management systems.

Learning management systems (LMS) are defined as "a network-based infrastructure to deliver and manage curricular content, communication, grading, and administration of the course; it is used extensively in traditional face-to-face classroom and distance-learning environments alike" (Ferster, 2014, p. 129). Learning management systems are also referred to "as 'learning platforms', 'distributed learning systems', 'course management systems', 'content management systems', 'portals', and 'instructional management systems', [and] they combine a range of course or subject management and pedagogical tools to provide a means of designing, building and delivering online learning environments" (Coates, James, & Baldwin, 2005, p. 20). With several features modeled from findings in the Athena Project at MIT, LMS continue to be

popular means to centralize and coordinate learning. Current popular LMS include Blackboard, Moodle, and Sakai.

LMS were critical in the development of adaptive learning, as they are the platforms on which most adaptive learning systems are built, accessed through, or modeled after, making their development a critical component of the adaptive learning movement (Newman et al., 2013; Ruff, 2019; Weisser, 2017). Standalone adaptive learning systems are also considered LMS. The first LMS was FirstClass by SoftArc, released in 1990 (Chaubey & Bhattacharya, 2015). Between their introduction and the early 2000s, LMS matured and were adopted by many universities worldwide (Coates et al., 2005).

The development of LMS into a staple in higher education came about as a result of the influence of academic capitalism. The fact that "most LMS were commercialized after originally being university development projects, rather than as direct results of business development activities" (Coates et al., 2005, p. 21) demonstrates the close ties between higher education and the market and how higher education began to show market-like behavior. Globalization also played a role in the proliferation of LMS. Between 1998 and 2002, two prominent LMS, WebCT and Blackboard LMS, grew from in-house university developments in North America to dominant educational systems worldwide (Coates et al., 2005). By 2002, 70% of institutions in Australia, the United Kingdom and Canada and between 55% and 62% of institutions in South Africa, Finland, the Netherlands and the USA used WebCT or Blackboard (Coates et al., 2005).

There were five primary drivers behind LMS adoptions, all of which were tied to academic capitalism.

1. LMS provided a means to increase teaching efficiency by facilitating the delivery of large-scale, flexible learning programs and "the identification and use of resources,

communication and conferencing, activities and assessments, collaborative work, and student management and support" (Coates et al., 2005, p. 23).

2. LMS promised enriched learning experiences grounded in proven learning theories (Coates et al., 2005).
3. Learner expectations for the use of advanced technologies and the "information age-mindset" drove higher education to adopt LMS (Coates et al., 2005; Green & Gilbert, 1995).
4. Competition pushed traditional institutions to embrace new technologies for a competitive edge in the development and expansion of institutional programs (Garrison, 2011).
5. LMS provided universities the ability to control and regulate instruction "by offering templates that assure order and neatness, and facilitate the control of quality" (Coates et al., 2005, p. 25).

The last driver alone drew considerable pushback from instructors over the imposition of control over work that was traditionally considered independent of managerial or institutional influence. These drivers are nearly identical to the drivers for adaptive learning, which is receiving much the same response as LMS. The drivers and criticisms for adaptive learning are covered in the next chapter.

The Open Learning Initiative.

The Open Learning Initiative (OLI) was created at Carnegie Mellon University in 2002 through a grant from the William and Flora Hewlett Foundation to address the challenges of enacting online instruction that maximizes the benefits of technology, rather than simply

moving the traditional classroom-based model to the web (Strader & Thille, 2012). The OLI set out to solve five limitations of traditional instruction:

1. Many instructors teach to a certain percentile of the class.
2. Students frequently do not receive immediate feedback crucial to the learning process.
3. In all but the smallest classes, the student's knowledge state is a black box to the instructor.
4. Degrees favor time spent in a classroom over demonstration of competency.
5. There is great inefficiency in creating instruction within higher education (Strader & Thille, 2012, pp. 202–203).

To accomplish their goal, the OLI created an online course environment that took advantage of new technological developments and advancements in human learning (Strader & Thille, 2012). The result was a learning system that allowed learners to set their own pace through the content, provided immediate feedback, assessed the learner's knowledge state and competency, and minimized the amount of resources needed to create a course (Strader & Thille, 2012). It used analytics and multiple feedback loops in a personalized learning environment to "deliver course content in a completely adaptive manner" (Strader & Thille, 2012, p. 208). What the OLI built was a practical example of personalized learning though technology that incorporated many of the functions of what we now call adaptive learning. The OLI's boasts that it could minimize the resources needed to provide instruction, improve quality, and make education more accessible than traditional instruction brought a renewed focus on technology in teaching and learning.

Massive Open Online Courses.

Massive Open Online Courses, or MOOCs, are online courses that are open to anyone and typically include a large number of simultaneous learners. The first MOOC was created in Canada in 2008 by educator and theorist George Siemens and researcher Stephen Downes when they offered the course Connectivism and Connective Knowledge (CCK08). Their course was designed for 25 enrolled students, but when opened up for any learner who wished to register worldwide over 2,300 people participated in the course (Yuan & Powell, 2013). MOOCs began to gain traction in U.S. higher education in 2011. The first modern U.S. MOOC was offered in October 2011 by Stanford professor Sebastian Thrun and Google's Peter Norvig on the Introduction of Computer Science (CS221) to 160,000 registered users (Ferster, 2014).

MOOCs prompted an increased focus on higher education from governments and market forces. MOOCs also generated significant interest and media attention from higher education and venture capitalists that saw business opportunities in the mass distribution of education (Yuan & Powell, 2013). Several MOOC platforms developed and offered courses, independently or in collaboration with higher education institutions, and some higher education institutions began "engaging and experimenting with MOOCs for the purpose of expanding access, marketing and branding, as well as the potential of developing new revenue streams" (Yuan & Powell, 2013, p. 3).

Many of the first MOOC developers credit Salman Khan as an inspiration for their move into online education, including Sebastian Thrun (Ferster, 2014). Salman Khan started the non-profit Khan Academy in 2008 with the vision to "use Internet-based computing to freely provide a world-class education to anyone, anywhere" (Ferster, 2014, p. 132). The Khan Academy, which is still going strong, hosts 18 million users monthly with content in 40 languages and is

used in more than 190 countries (Khan Academy, 2019). It offers free content from preschool to early college on a wide range of academic subjects, including math and science, and practice and pre-courses for the SAT and LSAT tests (Khan Academy, 2019). The Khan Academy is powered by a personalized learning system that allows learners to set their own pace and lets instructors track progress, identify knowledge gaps, and provide personal attention.

In 2011, after hearing Khan speak about his "one world classroom" with Bill Gates, who called Khan's ideas "the future of education," Thrun formed a company now called Udacity (Ferster, 2014). Under Thrun's vision, Udacity saw "a potential of revenue opportunities, such as charging learners for help from teaching assistants, credentialing, and providing recruitment service identifying their strongest candidates for industry" (Ferster, 2014, p. 144). Udacity, originally a MOOC provider, is now one of the leading providers of adaptive learning systems. Massive interest in Thrun's CS221 also impressed Stanford professor Andrew Ng. In 2012, Ng and colleague Daphne Koller saw an opportunity and formed the company Coursera, funded by $65 million in venture capital (Ferster, 2014). With over 30 million users, Coursera is currently the biggest MOOC provider in the world (Almanac 2018, 2018). It has partnered with over 160 universities and 20 industry partners, such as Intel and IBM, across 46 countries and offers over 3,600 online courses and credentials for over 300 specializations (Coursera, 2019; Shah & Laurie Pickard, 2019).

CHAPTER 4

The Adaptive Learning Movement

Prior to 2013, there was a notable increase in attention for adaptive learning in higher education and the educational technology market, but beginning in 2013, adaptive learning experienced a dramatic rise in interest (Oxman & Wong, 2014). Higher education institutions, governments, businesses, corporations, and individuals began to intently focus on adaptive learning, each for their own gain, around this time. This peak in interest was the culmination of the environment that academic capitalism helped to shape wherein adaptive learning was not only possible, but could also be both beneficial and lucrative. Since then, adaptive learning has been making headway in higher education, with and ebb and flow, although its future is uncertain.

This chapter begins with a table view of adaptive learning activity in higher education, which highlights the attention surrounding adaptive learning in recent years, and ends with an account of the use of adaptive learning at the University of Central Florida (UCF), one of the largest implementations of adaptive learning to date. The account is composed from unstructured personal interviews with UCF staff and published studies on the use of adaptive learning at UCF. It is intended to provide insights into the practical use of adaptive learning that came about during the adaptive learning movement.

Timeline of a Movement

Table 1 shows a timeline of the increased activity surrounding adaptive learning in higher education between 2011 and 2019, with a notable increase in activity in 2013, marked as the start of the adaptive learning movement.

Table 1: Adaptive Learning Movement Timeline 2011-2019

Year	Adaptive Learning Activity
2011	Apollo Education Group, University of Phoenix owner, purchases Carnegie learning for $75 Million (Oxman & Wong, 2014)
2011	Arizona State University begins using adaptive courseware using the Knewton product (Sclater et al., 2016)
2011	Partnership between Knewton and Pearson, the leading publisher of educational content, for Knewton to power Pearson's MyLabs products (Oxman & Wong, 2014)
2012	Colorado Technical University begins piloting adaptive learning using the intellipath platform (Johnson, 2016)
2012	Forbes Lists Adaptive Learning as one of 5 school technologies to watch (Savitz, 2012)
2012	Macmillan acquires PrepU, which offers adaptive testing systems in nursing products (Oxman & Wong, 2014)
2013	Career Education Corporation (CEC, owner of American InterContinental University, Colorado Technical University, International Academy of Design & Technology, and cooking school Le Cordon Bleu) partnered with CCKF to build 300 adaptive courses using its adaptive learning system RealizeIt, which will be branded Intelli-Path for CEC (Oxman & Wong, 2014, p. 12)
2013	Elsevier partnered with Cerego, a memory-building system originally created for language learning (Oxman & Wong, 2014, p. 12)
2013	Gartner's Hype Cycle for Education 2013 lists adaptive learning interest at its peak, with mainstream adoption in 5 to 10 years (Lowendahl, 2013)
2013	Kaplan acquired Grockit (an adaptive test-prep start-up) (Oxman & Wong, 2014, p. 12)
2013	Knewton partnered with additional publishers, including Cambridge University Press and Houghton Mifflin Harcourt (Oxman & Wong, 2014, p. 12)
2013	Learning Management System (LMS) provider Desire2Learn purchased Knowillage Systems, a start-up with an adaptive learning and analytics system called LeaP (Oxman & Wong, 2014, p. 12)
2013	McGraw-Hill purchased ALEKS (it had previously been the system's distributor); (Oxman & Wong, 2014, p. 12)
2013	The Bill & Melinda Gates Foundation calls for proposals for a new Adaptive Learning Market Acceleration Program (ALMAP) and publishes their report with Tyton Partners titled *Learning to Adapt: A Case for Accelerating Adaptive Learning in Higher Education* (Johanes & Lagerstrom, 2017)
2013	Wiley partnered with SnapWiz to build its adaptive learning system into Wiley's online environment, re-branded WileyPLUS (Oxman & Wong, 2014, p. 12)
2014	Educational technology startup Lrnr Adaptive Learning Solutions announces partnership with OpenStax College, the non-profit initiative at Rice University (Pochys Ventures, 2014)
2014	The University of Akron and Georgia State University receive funding for adaptive learning projects from the Bill & Melinda Gates Foundation, administered by the APLU. They each received "$225,000 as part of the Transformational Planning Grant (TPG) project to research, develop, and test new, scalable university business models that can increase access, improve success rates, and find greater cost efficiencies" (APLU, 2014)
2014	The University of Central Florida begins piloting courses using the adaptive learning system Realizeit (Dziuban, Moskal, Johnson, & Evans, 2017)

Table 1 (cont'd)

2015	D2L enters the adaptive learning market with LeaP, their embedded adaptive engine (Fain, 2015)
2015	Knewton launches free adaptive learning platform for anyone to use, calling it a "friendly robot-tutor in the sky" (Schaffhauser, 2015)
2016	Tyton Partners and the Bill & Melinda Gates Foundations publish their adaptive learning findings, in a follow-up to their 2013 Learning to Adapt report, titled *Learning to Adapt 2.0: The Evolution of Adaptive Learning in Higher Education* (Newman et al., 2016)
2016	National Louis University Launches Adaptive Learning Program developed using Acrobatiq (Hart, 2016)
2016	The APLUs Personalized Learning Consortium (PLC), funded by the Bill & Melinda Gates Foundation, announces awards for seven public research universities to accelerate use of adaptive courseware to improve undergraduate education. The universities are: Arizona State University, Colorado State University, Georgia State University, Northern Arizona University, Oregon State University, Portland State University, and the University of Mississippi
2016	SRI International and the Bill & Melinda Gates foundation find inconclusive results on the ability for adaptive learning to improve outcomes and lower costs, but finds high engagement and satisfaction in their ALMAP study final report (Yarnall, Means, & Wetzel, 2016)
2017	Pearson exits partnership with Knewton and launches its own adaptive learning engine (Wan, 2017)
2017	McGraw-Hill Launches Connect2, their new approach to higher education course design and management using adaptive learning (Chang, 2017)
2017	Harvard University begins experimenting with the use of adaptive functionality in one of its massive open online courses (MOOCs).(Schaffhauser, 2017)
2018	Knewton launches direct to higher education adaptive learning platform called Alta (McKenzie, 2019)
2018	VitalSource acquires Acrobatiq, Carnegie Mellon University's spinoff from the Open Learning Initiative (Hunt, 2018)
2018	DreamBox Learning, one of the best funded startups in education, receives $130M in growth equity (Harris, 2018)
2019	Wiley Education buys Knewton after the company struggled to deliver on adaptive learning and built up debt. (McKenzie, 2019)
2019	Bob Ubell publishes critical review of the adaptive learning market categorizing recent acquisitions as the "disillusionment phase" of the innovation (Ubell, 2019)
2019	ASU develops "the world's first adaptive-learning biology degree" (Leander, 2019)
2019	Center for Research and Reform in Education at Johns Hopkins University finds adaptive learning is linked to better test performance (Schaffhauser, 2019)

While the table is not all-inclusive of adaptive learning activities within those years, there is consensus that interest in adaptive learning rose sharply in 2013 (Lowendahl, 2013; Oxman & Wong, 2014). The series of adaptive learning system adoptions and efforts across higher

education and the market in 2013 and subsequent years are part of the larger movement for its use in education—the adaptive learning movement. During this time, boundaries between companies, higher education institutions, and governments became indistinguishable. The following sections provide details on significant projects and noteworthy changes that have influenced adaptive learning since the start of the adaptive learning movement.

Adaptive Learning Market Acceleration Program

In 2013, The Bill & Melinda Gates Foundation initiated the Adaptive Learning Market Acceleration Program (ALMAP). The goal of the program was to provide an evidence-based understanding of how adaptive learning technologies could improve opportunities for low-income learners to complete postsecondary credentials (Yarnall et al., 2016). Between summer 2013 and winter 2015, the ALMAP grant program provided seed money for 14 higher education institutions to incorporate nine adaptive learning products into 23 courses to measure the effects on student outcomes and gather data on cost impacts, student satisfaction, and instructor satisfaction (Yarnall et al., 2016). Over the course of three academic terms, more than 19,500 unique students, in classes taught by over 280 unique instructors, participated in adaptive learning courses (Yarnall et al., 2016).

ALMAP participants used adaptive courseware to make changes in course delivery for subjects including psychology, biology, business, marketing, and economics. The changes were organized into three categories:

- Blended Adaptive vs. Lecture: adaptive courseware was used as part of a shift from traditional lecture to blended instruction.
- Online Adaptive vs. Online: adaptive courseware was used as an enhancement to existing online courses.

- Blended Adaptive vs. Blended: adaptive courseware was swapped into face-to-face courses already using blends of classroom-based and online approaches to support learning (Yarnall et al., 2016, p. ES-ii).

In 2016, ALMAP produced a report highlighting key findings including: slightly higher average course grades, modest positive improvements on learning assessment scores, no effect on course completion rates, and a positive impact on student learning by switching from a lecture format to adaptive blended instruction (Yarnall et al., 2016). Other findings include lower ongoing costs for the majority of cases, an increasing need for instructor time, and a 74% satisfaction rate for instructors and students (Yarnall et al., 2016). These findings have been used to both promote and criticize adaptive learning.

Content Publishers in Adaptive Learning

Slaughter and Rhoades (2004) state that academic capitalism is evident in the "intensified commercialization of instruction, educational materials, and software/courseware" (p. 10). The increasing role of content publishers and business startups in the adaptive learning movement is a result of academic capitalism. Historically, the connection between higher education and content publishers has been the textbook. Up until the rise of knowledge economy, the textbook was the primary source of subject matter content in a higher education institution course, and until recent years, content publishers held nearly unfettered power in the $7 billion dollar college textbook industry (Mitchell, 2014).

The arrival of the Internet and online learning provided different avenues for the delivery of course materials, such as video lectures, learning management systems, and web pages. Additionally, rising textbook costs have pushed learners to skip buying textbooks, download textbooks illegally, or buy used textbooks (Mitchell, 2014). Declining sales, such as the 71%

drop in higher education textbook revenue witnessed by publisher McGraw-Hill between 2010 and 2013, prompted a shift in content publishers' business models (Mitchell, 2014). This shift led to an interest in providing adaptive learning solutions or the acquisition of adaptive learning startups by content publishers. Table 1 shows a significant number of partnerships and acquisitions between content publishers, higher education institutions, and adaptive technology startups. Because course materials in adaptive learning systems are not provided through a textbook, adaptive learning is seen as a course material competitor for content publishers. By purchasing or partnering with actors providing adaptive learning, content publishers are seeking to maintain market and profit share in the increasingly competitive course material market.

Adaptive Learning at Work: An Account from the University of Central Florida

In the study of adaptive learning in American postsecondary education, the University of Central Florida (UCF) stands out as a leader in online instruction for the past two decades and an emerging leader in the use of adaptive learning as a practical methodology for instruction. UCF is listed as the largest higher education institution in the U.S. by undergraduate enrollment, at close to 59,000 undergraduate students in 2018, and remains one of the nation's largest education institutions by total enrollment (Kowarski, 2018; "UCF Facts 2018-19," 2018). It is classified as a public research university with very high research activity ("UCF Facts 2018-19," 2018). The primary driver for UCF's digital learning strategy has been to increase educational access, with online and blended learning accounting for the majority of UCF's enrollment growth (Dziuban et al., 2018). Between 1996, when the university offered its first online course, and the end of 2016, UCF had designed and developed over 19,000 fully online courses and 1,700 blended learning courses (Dziuban, Moskal, & Hartman, 2016). In the 2016-2017 academic year, 81% of

students took at least one online or blended course and 72% at least one fully online course (Dziuban et al., 2018).

Four main themes surround UCF's use of adaptive learning: first, UCF had access in mind when they chose adaptive learning; second, they chose to build an adaptive learning system as opposed to buying pre-built courses; third, faculty participation was a principal factor in choosing adaptive learning; and, fourth, measures of success for adaptive learning at UCF were student persistence and engagement. The following sections expand on these four main themes and end with a few areas of importance that are revisited in the final chapter.

Methods and procedure.

This account is constructed from published introspective studies by researchers at UCF, supplemented by anonymous unstructured personal interviews with a senior instructional designer, a faculty researcher, and an online learning administrator at UCF. I chose UCF because it was one of the most widely cited and large-scale implementations of adaptive learning outside of funded research projects, such as ALMAP, which may have limited the disclosure of information. The published introspective studies, by Dziuban et al. (2016, 2017) and other UCF staff, provided the history of UCF's decision on the use of adaptive learning, which is incorporated in subsequent sections, and assisted in developing a clear plan regarding the focus and goals of the personal interviews. The focus of the interviews were UCF staff and administrators and the goals were to identify the history, current use, and future goals of adaptive learning at UCF. Subjects for the study were chosen from the contact listing on UCF's Division of Digital Learning's website and from contacts identified during the personal interviews (UCF Digital Learning, n.d.). Each subject was invited to participate in a thirty-minute Zoom web conference via email where they were asked open-ended questions about the history, current use,

and future of adaptive learning at UCF that then developed into organic discussions. The unstructured personal interview method was beneficial for developing a broad understanding of the use of adaptive learning at UCF, which was sufficient for this study. A detailed case study of the use of adaptive learning at UCF could be an area of focus for future research.

Choosing adaptive learning and faculty participation.

The use adaptive learning at UCF stemmed from the idea that adaptive learning showed promise as an innovative educational technology. They reached a decision to look for and pilot an adaptive learning system in 2014, at the start of the adaptive learning movement and before any strong data over its effectiveness was available (B. Chen, Bastedo, Kirkley, Stull, & Tojo, 2017; Dziuban et al., 2018; Dziuban, Moskal, et al., 2017). The decision began from what an online learning administrator called an "environmental scan". The person stated:

> In one sense, we're always kind of doing an environmental scan and, right, and going "What are the trends? Where are we?" And then you kind of look for something that's promising. And then you say, okay, well, that's really promising, let's pilot that, let's test that out. That looks really good. This has potential to scale. Let's move forward. So at one level, we're always doing that as a means of thinking about how to continue to innovate and advance and not just sit on our laurels, not get stagnant, not just kind of do things the way that we've been doing it. (online learning administrator)

After loosely recognizing its potential, UCF began researching the benefits of adaptive learning and identifying how it could enhance their online learning offerings. They noted three areas where adaptive learning would likely provide some benefits: online personalized instruction would lead to improvements to student success in a few key courses, improvements to course quality, and greater access to underserved populations (Dziuban et al., 2018; Dziuban,

Moskal, et al., 2017). The idea that adaptive learning could improve accessibility had a particular appeal for a public institution serving in Florida, where there is rising number of traditionally underrepresented students graduating high school and looking to enroll in higher education (Gibney, Dunn, Smerdon, Kim, & Perrault, 2018). One particularly impassioned UCF staff member had this to say about the potential for adaptive learning for improving access:

> My take on that is this: that if you live in the lower economic quartile in this country, the expectation for your college graduation in these communities is 10 percent, that the odds are basically really stacked against you for any number of reasons, because growing up in poverty is a great deal of burden on your cognitive existence. You have so many things to manage simply being poor. But by the time you get to Michigan State or UCF or Stanford or wherever you go, you have basically burned up most of your cognitive bandwidth. Living now, I don't know if that's exactly accurate, but I know the stresses on our poor underserved populations are very tough. It stresses you're managing money, you're bad, you're managing a part-time job, managing family, maybe managing children, grandparents. You're managing so many things simply existing that if any one of those dominoes topple, they all topple. So, you're constantly juggling and you have to, you have to tunnel. Your car breaks, what do you do? You know, if you get your car repairs, you get your car repaired, you can't pay your rent. You know, that kind of management sort of situation. If you take public transportation, you're late to work and you might get fired. Those are the kinds of things you get on our campus. And you just don't have the bandwidth to deal with all of the things without that wrapping. So I think what adaptive learning has the potential for is serving this underserved population in terms of dealing with how do I grapple with the kinds of things that if I'm suddenly thrown into

> intermediate algebra because I didn't pass the math placement examination, that if I have extended time to learn it, that if I miss a class or I missed two classes, I'm basically lost. Adaptive learning presents an opportunity for you to succeed. I think that's the problem. I think it has the potential for solving the greatest economic problem in our country. (faculty researcher)

The Center for Distributed Learning (CDL), the central agent for online learning at UCF whose mission includes investigating and delivering new technologies in online learning, led the charge on the exploration and implementation of adaptive learning ("CDL Core Values," n.d.). In 2014, UCF formed a committee of faculty members, executives, instructional designers, and technologists who examined several adaptive learning systems, as described by a senior instructional designer. After extensive discussions and demonstrations, UCF chose Realizeit as the adaptive learning system for a pilot (Dziuban et al., 2018; Dziuban, Moskal, et al., 2017).

While the CDL provided initial support for adaptive learning, the use of adaptive learning hinged on the support of faculty. With this in mind, faculty were a key part of the decision for UCF to move forward with adaptive learning and in choosing Realizeit. The decision process was described as:

> There was a sort of notion in the faculty that [adaptive learning] made sense. You know, it was discussed with faculty and faculty, you know, wrap their head around the idea that this had some potential. So, what we did at UCF is we had several quote-unquote, vendors come in and make presentations to faculty and they looked at several platforms. And what happened is the legacy platform at the moment is Realizeit. And that was a faculty decision and that this might be a way to go about this in terms of altering the instructional paradigm in a way that responds to student's needs, basically all shrugging

the time variable. Of course, then what we did is we've implemented on a pilot stage. (faculty researcher)

Faculty had a great deal of input on whether UCF would purchase off-the-shelf courseware or build the courses themselves. Choosing off-the-shelf courseware would have made startup easy, but the minimal or no instructional modifications and lack of faculty input in pre-constructed courses was not appealing to UCF faculty (Dziuban, Moskal, et al., 2017). Creating adaptive learning courses is time-consuming, requiring a significant upfront workload in the design and development of courses and course assessments (Dziuban et al., 2018; Johanes & Lagerstrom, 2017; Vignare et al., 2018). UCF faculty chose a content-agnostic system that was flexible, but required a significant amount of upfront work and continued support. Although the "time variable" is one of the largest criticisms by faculty on the use of adaptive learning, UCF faculty were intent on spending the time if it meant better outcomes.

Implementation, ongoing support, and choosing to build.

Three faculty members volunteered to develop the first courses for the pilot (Dziuban et al., 2018). In Fall 2014, UCF offered two adaptive courses in General Psychology and Pathophysiology, with 154 enrolled students, and then added College Algebra the following Spring (B. Chen et al., 2017; Dziuban et al., 2018).

Support for the development and implementation of the courses is provided by the CDL in the form of instructional designers (B. Chen et al., 2017). Instructional designers work with faculty members individually and "help them understand the features of the adaptive platform system while creating pedagogically sound courses" (Dziuban et al., 2018, p. 13). The instructional designers "are assigned to faculty for the duration of the course administration. In addition, the CDL has graphic artists, a video team, and programmers who support faculty as

they design their online instructional components and teach the digital learning courses" (Dziuban et al., 2018, p. 13). A group of instructional designers at UCF outlined the following challenges they experienced during the construction of the adaptive courses in Realizeit:

- Building an adaptive course proved to be quite time consuming, which was difficult for busy faculty. Although our faculty as a whole preferred the ability to create and modify content as needed, they quickly saw that for the system to work properly it would require much more content than they had available.
- One of the most thought-provoking changes in adaptive learning is moving from strictly summative to formative assessment. This has been a leap for many faculty since summative assessments have been a central part of education for so long. Moving to real-time formative assessments—including interactive content with immediate feedback—can be difficult for faculty members.
- A third challenge that revealed itself early on was how to approach the course organization. Most faculty were not ready to relinquish projects and other forms of assessment to have what we called a "true adaptive" course where all modules were fully built in Realizeit. To alleviate these issues, instructors can now integrate adaptive learning components into courses as supplements while still keeping other components as integral parts of the course. (B. Chen et al., 2017, pp. 6–7)

The implementation and ongoing support for adaptive learning turned out to be a large undertaking for the instructional designers and the institution. One senior instructional designer at UCF describes the support for such a large undertaking, versus other face-to-face or blended courses they work on, by stating that:

> So here with us, we have a special team. It started with one instructional designer. And now after over four years, we have five instructional designers working on the whole initiative. But still, this is way more work than just the five of us can handle. (senior instructional designer)

Diving into the decision to build the courses themselves and support them, the online learning administrator credited the culture of UCF, which focuses on faculty and outcomes for this decision. They stated that:

> [There is] a kind of cultural tendency here. Our general tendency, kind of related to the build versus buy, is our approach is to is to work hand-in-glove with the faculty members wherever we can and invest in the faculty number in terms of their thinking about course design, and not just take a kind of a black box commercial off-the-shelf product and deploy it. (online learning administrator)

The increase in instructional design staff was, therefore, necessary to support the culture of working closely with faculty. The faculty researcher stated that:

> We had to make room for it, we knew that support was necessary, we have to support our faculty, and we have a much broader perspective where we try to eliminate most of the technology burdens for faculty so they can concentrate on pedagogy. And designing an adaptive learning course is difficult because the granularity of the course has to be consistent. (faculty researcher)

For UCF, adaptive learning elevated the need for more non-faculty support staff to assist faculty in the development and ongoing support of courses. In the accessibility discussion, one faculty member, with support, can facilitate more courses than face-to-face alone, making it possible to offer more quality courses that promise better outcomes to a wider range of students.

Thus, the appeal of adaptive learning to UCF was not overshadowed by the conversation around how much time it would take to build and support the courses.

Measuring success.

Measuring the success of adaptive learning at UCF centers on the positive impact of outcomes beyond "the degree to which students succeed in mastering targeted learning objectives or outcomes" (Dziuban, Moskal, et al., 2017, p. 28). This means that, instead of measurements such as *the degree to which students taking an adaptive course did better on an examination than those students who completed a non-adaptive version of the same course*, adaptive learning at UCF is measured by outcomes in student persistence and engagement, such as *the percent of learners who indicated that adaptive learning helped them learn better* (Dziuban, Moskal, et al., 2017). The use of persistence and engagement measurements bypasses the mixed results that other researchers, such as Griff & Matter (2013) and Murray & Pérez (2015), have found in trying to determine the effectiveness of adaptive learning using the degree of learner success and goes directly to the measurements that these same researchers have shown adaptive learning does have a positive impact on (Dziuban, Moskal, et al., 2017). This approach considers the "effectiveness of adaptive learning in actual practice" (Dziuban, Moskal, et al., 2017, p. 28) instead of a complex comparison across dissimilar instances with immeasurable factors that could contribute to variations in measures.

The success of adaptive learning at UCF is gauged by surveys of student persistence and engagement. One such survey gauging learner reactions and experiences with adaptive learning after the initial pilot courses with Realizeit found that overall, students felt positive about their experiences using RealizeIt (Dziuban, Howlin, Johnson, & Moskal, 2017). The survey found:

- 78% of learners indicated that adaptive learning helped them learn better.

- 77% of learners indicated that adaptive learning feedback helped them learn better.
- 63% of learners indicated that personalization helped them learn better.
- 75% of learners indicated that more engagement helped them learn better.
- 78% of learners indicated a willingness to take another adaptive learning course (Dziuban, Howlin, et al., 2017).

This feedback immediately after the pilot courses supported the continued use of adaptive learning at UCF. Over the last four years, the number of adaptive courses offered at UCF has grown substantially. In May 2018, UCF had 22 adaptive learning courses, for a total of 66 instances, with 3,325 students enrolled in the courses (Dziuban et al., 2018). They continue to offer new courses each year in what may be the largest instance of adaptive learning use at a U.S. public or private research institution.

Areas of note.

In the compilation of this account, several areas of note, some of which will be covered more generally in the next chapter, should be pointed out. First, the use of adaptive learning in "online and blended courses is supported through the university distributed learning student fee as established by Florida statute" (Dziuban et al., 2018, p. 13). Costs for the use of Realizeit at UCF are passed on to the student in a per credit hour fee. Rising costs make higher education less accessible to students and families who may not be able to afford the incremental cost of fees (Immerwahr, Johnson, & Gasbarra, 2008). Second, researchers at UCF have noted a significant change in the role of a faculty member in an adaptive learning class (B. Chen et al., 2017; Dziuban et al., 2016). Researchers stated that:

> Faculty are now asked to consider newer teaching strategies that emphasize facilitation (e.g., no longer being the "sage on the stage," but now becoming the "guide on the side").

> With students following their own personalized paths, the instructor starts to observe them through intricate learning analytics, which suggest to faculty when and where to intervene. They no longer need to wait for a midterm exam to gauge issues in student learning—they can instead detect potential problems early. (B. Chen et al., 2017, p. 6)

Finally, there has been significant pushback on the recent expansion of UCF's coursework with Realizeit and the UCF College of Business. A format change to include less in-person and more online courses implemented in Fall 2018 created a "mandatory reduced-seating format in the College of Business Administration" (Adeyemo, 2018, para. 3). The format changes include the use of Realizeit. One student-published article described part of the issue as being directly related to the use of the adaptive learning software: "Realizeit, a program used by many students in the College of Business Administration, has been the subject of student complaints because of its 'glitches' and counter-intuitive user experience" (Adeyemo, 2018, para. 20). The format change sparked a petition aimed at a direct result of the expanded reach and access UCF is actively pursuing with adaptive learning. One article in the *Orlando Sentinel* newspaper described the issue in the following excerpt:

> Tensions also flared last fall when more than 2,000 people, including students, alumni and parents signed a petition complaining about a new course format in the College of Business Administration that placed roughly 1,200 students in each course and most of the instruction was online.
>
> College leaders acknowledged the courses were designed to be an economical way to serve 8,500 undergraduates but also said the approach offered benefits, including pushing students to take more responsibility for their own learning.

> Supersized courses are becoming increasingly common at UCF, where the number of sections with 100 or more undergraduates grew between 2013 and 2018, according to data submitted to the U.S. Department of Education. And the total number of undergraduate course sections shrunk during that time, even as enrollment increased. (Martin, 2019, paras. 19–21)

This pushback has led to a strategy defending UCF's expansion and reliance on online learning by the interim president, Thad Seymour (Martin, 2019). Where that leaves Realizeit and adaptive learning at UCF is yet to be determined.

CHAPTER 5

Drivers and Criticisms of the Adaptive Learning Movement

Higher education is in an environment where academic capitalism is influencing processes and practices at many levels of an institution. Today, "nearly all aspects of higher education (e.g., student recruitment and learning, governance, organizational and administration and strategy, public policy, and the academic profession) are embedded in the political economy with links to the market, nonprofit and nongovernmental organizations, and the state" (Kauppinen & Cantwell, 2014, p. 3). This environment has given rise to a movement to use adaptive learning across higher education, challenging traditional views of higher education teaching, learning, and administration, and even calling into question the goal of higher education in general (Välimaa, 2014).

Adaptive learning and its growing popularity in higher education are products of academic capitalism. Without academic capitalism, the technology on which adaptive learning is built, the drivers that have prompted its use, and the organizations that supported and developed it would not have brought higher education to the point where adaptive learning is possible, feasible, and sought after. Adaptive learning remains in a constant state of flux. Like many new developments in higher education, there are those who support the use of adaptive learning and those who criticize it.

I believe that the majority of reasons to support or stand against adaptive learning are heavily influenced by academic capitalism. This is the interplay of actors and their environment on the institutionalization of the innovation. In this chapter, I group together some of the common drivers and criticisms of adaptive learning and explain how they relate to academic capitalism in American public and private research institutions. I focus on research institutions

due to their direct contributions to the knowledge economy by their commitment to discovery, innovation, and knowledge production (Crow & Dabars, 2015).

Purpose of Higher Education

Underlying several of the criticisms for adaptive learning in higher education are two competing ideologies over the purpose of higher education: the classical and utilitarian perspectives. Historically, the purpose of higher education institutions was to prepare learners for lives of public service, to develop leaders, and to advance knowledge through research: the classical perspective (Chan, 2016; Johann Neem, 2013; Williamson et al., 1949). Competing with this historical view is the thought that higher education should prepare learners with the skills, knowledge, and ethical responsibility to meet the workforce needs of society and participate in the global economy: the utilitarian perspective (Chan, 2016; Spellings, 2006).

While these two ideologies long existed in a volatile equilibrium, the balance tipped from the classical perspective to a utilitarian one in the late 1960s, when sentiment changed away from classical views of higher education and these views were dubbed an "intellectual luxury" (Berrett, 2015). The balance shifted even more toward the utilitarian perspective during the rise of the knowledge economy, when participation in the global economy became almost compulsory for higher education institutions to maintain their relevance on the national and global scales (Slaughter, 2014; Slaughter & Rhoades, 2004).

Today, the classical ideology still exists as the public good knowledge/learning regime and it competes with the dominant utilitarian ideology, which since the rise of the knowledge economy is called the academic capitalist knowledge/learning regime (Slaughter & Rhoades, 2004). Those who adhere to the public good knowledge/learning regime argue the need for a

massive tilt toward academic capitalism in higher education. The following statement is an example of the public good knowledge/learning regime sentiment towards academic capitalism.

> In the United States, many of the problems in higher education can be linked to low funding, the domination of universities by market mechanisms, public education's move toward privatization, the intrusion of the national security state, and the lack of faculty self-governance. All of this not only contradicts the culture and democratic value of higher education, but also makes a mockery of the very meaning and mission of the university. Universities and colleges have been largely abandoned as democratic public spheres dedicated to providing a public service, expanding upon humankind's great intellectual and cultural achievements, and educating future generations to be able to confront the challenges of a global democracy. As a core political and civic institution, higher education no longer is committed to addressing social problems. Instead, it has become an institution that in its drive to become a primary accomplice to corporate values and power makes social problems both irrelevant and invisible (Giroux, 2010, p. 186).

Arguments against academic capitalism include some of the drivers that have made, and are still making, the adaptive learning movement possible—such as workforce development, increased efficiencies, and the pursuit of external revenues through instruction and curriculum (Slaughter & Rhoades, 2004). The following sections outline some of the drivers and provide critical perspectives from the public good knowledge/learning regime that aim to maintain, or even bring back, practices and processes based on the classical ideology of higher education.

Driver: workforce development.

One of the underlying drivers for using adaptive learning in higher education is the need for an educated workforce to meet the demands of the knowledge economy and beyond. Adaptive learning systems are touted as being able to improve the number and quality of educated graduates to meet the economic demand for human capital. Human capital is the collective skills possessed by the labor force that make it a resource or asset, including the education investments in people that increase an individual's productivity (C. Goldin, 2016). In essence, adaptive learning helps higher education prepare learners to contribute to the global economy, a process that falls under the description of academic capitalism. There are two parts to this driver: the need from government and the market for educated workers, and the desire to prepare learners to meet these needs by higher education (Chan, 2016; J. King & South, 2017; Slaughter & Rhoades, 2004; Spellings, 2006).

The economic impact of investments in human capital for governments and the market create the need for knowledgeable workers to contribute to the economy. In their landmark book *The Race Between Education and Technology*, economists Claudia Goldin and Lawrence Katz (2008) show, using economic modeling, that the increasing education attainment of the workforce between the twentieth and twenty-first centuries gave rise to the United States as an economic powerhouse. They found that "a greater level of education results in higher labor productivity" (C. D. Goldin & Katz, 2008, p. 2) and that rapid technological change increases the need for more educated workers. In order to maintain the economic standing of the United States and the productivity of the national market, particularly in the face of the *fourth industrial revolution*, investments in human capital must continue to rise (Schwab, 2016). The fourth industrial revolution is the current age, which is highlighted by smart and connected machines

and systems across physical, digital, and biological domains, and faster and wider-ranging emerging technologies and broad-based innovation worldwide (Schwab, 2016). In this age, not only are greater breadth and depth of knowledge required, but "so are complementary skills such as critical thinking, collaboration, creativity, and communication (often referred to as 21st century skills)" (U. J. Christensen, 2019, para. 3).

The World Economic Forum has characterized today's education and training systems as "largely inadequate" at meeting the demands of the workforce (U. J. Christensen, 2019). With new developments in artificial intelligence and machine learning, adaptive learning is seen by some outside higher education as an answer to education meeting the demands of the economy and the market. A recent article in Forbes stated that:

> Personalization and adaptive learning are definitely not the only answer, as technology alone cannot solve the education problem. But adaptive learning is an important answer that, when applied in a human-plus-machine approach, can transform education (U. J. Christensen, 2019, para. 15).

Governments and the market have a need for an educated workforce, and higher education research institutions are in position to supply the necessary human capital. "More and more knowledge inputs are increasingly required to perform almost any job in the ever more complex global knowledge economy, and American research universities are the principal source of the advanced education that produces a skilled workforce" (Crow & Dabars, 2015, p. 59). Public and private research institutions are continuously looking for opportunities to further their commitments to teaching, research, and public service, such as adaptive learning (Crow & Dabars, 2015). Adaptive learning has been gaining traction as a way to improve retention,

quality, and access, promising more graduates and graduates who are better prepared to meet the challenges of the new economy (Newman et al., 2016).

Criticism: resource shift.

Criticisms for the focus on an educated workforce include institutional decisions that have prompted "developments to make university courses and [programs] more relevant to the world of work" (Olssen & Peters, 2005, p. 328). The focus on workforce development has led to a resource concentration on work-based learning, evidence-based practice, and a "general shift towards vocationalism and professionalism in higher education" (Olssen & Peters, 2005, p. 330). This concentration leads to inattention to other areas of higher education that are not overtly seem as contributing to the creation of an educated workforce.

For example, the continuing focus on science, technology, engineering, and math (STEM) to meet the future economic needs oftentimes ignores the value of liberal arts and the classical ideology of higher education (Bevins, 2011). The focus on STEM is not only internal, such as in institutional priorities and resources, but also external, in the links between higher education and government resource drivers. "Many state governors view STEM (science, technology, engineering, and mathematics) education as key to economic growth and development and are thus producing legislation and initiatives intended to increase the production of STEM degrees at public institutions of higher education," while no such push exists for many liberal arts schools and programs (Bevins, 2011, p. 12). Critics argue that too much focus on STEM and workforce preparation at research institutions has diminished the focus on fields not seen as directly affecting workforce preparation, relegating the work of instruction in these courses to non-faculty instructors or other ill-suited personnel (Baltodano, 2012; Reingold, 2018). David Reingold, Dean of the College of Liberal Arts at Purdue

University, pushes back on "overly specialized STEM curriculum"(Reingold, 2018, para. 3) as he states:

> At a comprehensive public research university, having faculty teach introductory courses in the liberal arts is uncommon. In the humanities, that has more commonly become the domain of graduate teaching assistants. But we believe it is essential to build a new model of graduate education in the humanities, one in which our programs exist not merely to deliver undergraduate education but to offer important research opportunities alongside teaching experiences. (Reingold, 2018, para. 21)

Criticism: massification.

Critics also argue that the focus on workforce development and the use of adaptive learning continue to contribute to the massification of higher education, which is the rapid expansion of higher education and higher education enrollment that began in the 1960s and 1970s when "Western societies built welfare states after the Second World War in an effort to enhance the international competitive capacities of nation-states with the help of education and research" (Välimaa, 2014, pp. 42–43). "The United States was the first country to achieve mass higher education, with 40% of the age cohort attending post-secondary education in 1960" (Altbach et al., 2009, p. vi). Before the knowledge economy and academic capitalism, massification was the largest driver in the transformation of higher education.

Martin Trow, preeminent researcher on the massification of higher education, identified three different ways in which the growth of higher education manifested itself before the knowledge economy and continue on today (Trow, 2005). First, the *rate of growth*, where the number of learners increases exponentially over a short amount of time, places strains on existing structures of governance, administration, and other resources (Trow, 2005). Second,

growth affects the *absolute size* of institutions, such as in the number of learners, administrators, faculty, and physical size to accommodate expansion (Trow, 2005). And third, growth is reflected in changes to the *proportion of the relevant age group* enrolled in higher education, highlighting the recent profile change of the "traditional college student" (McPherson, 2017; Trow, 2005). Each of these manifestations continue to lead to a host of issues, as well as the introduction of innovations and market-like behaviors to address these issues.

As Trow stresses, massification changed the fundamental structure of who higher education served (Burrage, 2010). Massification converted higher education from an elite system to a mass system of higher education aimed at producing qualified workers for the labor markets (Burrage, 2010; Peters & Humes, 2003; Välimaa, 2014). This conversion changed the dynamics of teaching, learning, and administration of higher education wherein new practices and processes were necessary for the expanding numbers of different higher education learners. Most notably, massification increased the costs of higher education, necessitated the need for new pedagogical approaches, and shifted management structures from being led by academics to a new professional group of administrators (Välimaa, 2014). Some of this change from academics to other professionals stems from academic capitalism (Burrage, 2010). Via academic capitalism, "universities expand managerial capacity to monitor, incent, and discipline the increasingly differentiated faculty as well as the increasing number of nonacademic professionals that make up the growing tertiary workforce" (Slaughter, 2014, p. 13).

Ongoing massification practices in the knowledge economy led to the development of far-reaching educational technologies such as online learning, MOOCs, and adaptive learning. Massification has also led to the use of adaptive learning to offset its consequences, such as growing class sizes. "Growing class sizes have been a direct effect of massification as there has

been no proportionate increase in human, financial, and physical support from public sources in the higher education sector" (Hornsby & Osman, 2014, pp. 712–713). This means that as higher education enrollment grows, institutions have had to accommodate a greater number of students with less resources, oftentimes turning to innovations and market-like behaviors to counter this challenge (Hornsby & Osman, 2014). Adaptive learning is a result of the expansion of higher education for workforce development, and a contributor to the ongoing massification of higher education.

Iron Triangle of Education

Three concepts dominate discussions over concerns regarding higher education: the ever-increasing *cost* of higher education; the need to improve and maintain the *quality* of education; and the ability to provide *access* to a wide range of learners (Immerwahr et al., 2008). These three concepts—cost, quality, and access—exist in tension with each other and form the *Iron Triangle of Education,* (Immerwahr et al., 2008; J. King & South, 2017; Murray & Pérez, 2015). More often than not, improvements to any of the three concepts in higher education causes conflicts in one or both of the other concepts. For example, increasing access can dilute quality; improving quality leads to an increase in costs; and reducing costs can negatively impact quality and access (Duncan, 2009).

Educational technology has long been seen as a possible solution to the cost and scalability issues that arise from the use of pedagogy that aims to improve completion rates and scores of individual learners (J. King & South, 2017; Murray & Pérez, 2015). Adaptive learning has gained popularity and is often touted as a possible solution to the conundrum of the Iron Triangle of Education, a way by which higher education can lower costs, improve quality, and

extend access to an advanced education to a larger group of people (J. King & South, 2017; Murray & Pérez, 2015).

Critics argue that there is some cause to be wary of the technology, as the main drivers for adaptive learning are possible advances of academic capitalism with overall negative impacts to higher education. It is still too early to tell what the overall effects of adaptive learning will be, but the adaptive learning movement is part of the exploration by higher education as to whether adaptive learning can indeed solve the Iron Triangle. Adaptive learning shows promise, with early indicators showing that adaptive learning can indeed address the Iron Triangle of Education (Murray & Pérez, 2015; Yarnall et al., 2016). This section highlights each of the concepts in the Iron Triangle and details how adaptive learning drivers and criticisms in each concept could possibly result in changes to higher education.

Reducing cost.

Student loans currently make up the largest portion of U.S. non-housing debt, more so than credit cards and auto loans (Maldonado, 2018). The cost of an undergraduate degree has risen 213% at public institutions and 129% at private institutions since the late 1980s, after adjusting for inflation (Hoffower, 2019). Rising costs have made obtaining a college degree less advantageous, as the return on investment has fallen. Some of the most cited reasons for this increase include a surge in demand, an increase in financial aid, the decline in state funding, the need for more faculty and money to pay them, and inflating student services leading to an explosion of non-teaching personnel on campus (Hoffower, 2019).

In the face of these rising costs, higher education institutions are turning to innovations in online learning, such as adaptive learning, to reduce costs (Dusst & Winthrop, 2019; J. King & South, 2017; Murray & Pérez, 2015; Yarnall et al., 2016). Coursera, one of the leading adaptive learning systems, “offers a fully online master’s degree from the University of Pennsylvania in

computer and information technology for one-third the cost of the on-campus version" (Dusst & Winthrop, 2019, para. 10). Generally, higher education institutions that use online learning technology, such as adaptive learning, charge lower prices for online coursework (Deming, Goldin, Katz, & Yuchtman, 2015). There are also potential cost savings for individual students on course materials. Early adopters of adaptive learning systems "report that students' cost of [course] materials in the sections using adaptive courseware is lower than the cost of materials in nonadaptive sections" (Vignare et al., 2018, p. iv).

Additionally, higher education institutions looking to reduce the cost of higher education have turned to revenue maximizing or expansion opportunities. Adaptive learning, as a revenue tool, is driven by academic capitalism. Slaughter and Rhoades (2004) argue "that universities and colleges (and in some cases, students) have initiated aggressive pursuit of external revenues based on instruction and curriculum" (pg. 132), such as the need to increase enrollment via learning technologies like adaptive learning. On the other hand, critics argue that adaptive learning can increase overall costs due to the need for additional support personnel to implement and maintain adaptive learning systems.

Driver: financial focus.

For the eighth consecutive year, college enrollment in the U.S. has declined (Fain, 2019). Coupled with the decrease in state funding for public institutions, there is need for higher education institutions to focus on their finances, especially revenue stabilization and generation. This has led to a battle between higher education institutions to attract or maintain learners and their tuition dollars. Some, such as private research institutions, compete for a small group of highly qualified individuals by building new facilities, programs, and opportunities. Others, such as public research institutions, take a broad approach that aims to attract more learners by

expanding their reach to more learners with tools such as online learning (Kak, 2018; Simon, 2017). Adaptive learning can be a beneficial tool in increasing retention and graduation rates, which not only keeps tuition revenue steady but also attracts learners. It can also be used as a way to reach a larger audience with minimal efforts, thereby increasing tuition revenue via enrollment growth (J. King & South, 2017). As Phil Regier, dean for educational initiatives at Arizona State University, stated of students retained through their use of adaptive learning, "that is a revenue stream we wouldn't have if they quit" (Freda, 2016).

Criticism: increase in support staff.

Critics point out that adaptive learning requires more support staff in the form of technology specialists and instructional designers (Fahmy, 2004). Highlighted as one of the downsides to its use, adaptive learning is costly and requires extensive support typically beyond the expertise of a single faculty member. In the article *7 Things You Should Know About Adaptive Learning* (2017), the authors point out that:

> Adaptive learning can be costly and time consuming to implement. It requires detailed curriculum mapping and content development that supports learning objectives, and sometimes those objectives require delineation. Content has to be designed at the lesson and objective level, and concept interconnections must be determined across the course or across connected courses. (Moskal et al., 2017, p. 2)

Content design and the ongoing support of adaptive learning systems typically falls within the scope of work for information technology staff and instructional designers (Bastedo & Cavanagh, 2016). The adaptive learning system must be implemented and maintained, which can be as simple as purchasing access to on online system, or as complicated as installing a new system on campus servers with campus information technology staff's initial and ongoing

support. As one study pointed out, one of the pitfalls is that "creating an adaptive learning system can bankrupt an institution due to high cost in expertise, time, and capital" (Johanes & Lagerstrom, 2017, p. 11).

Additionally, content management requires a rigorous adherence to a content management process and strategy, typically led by instructional designers (Quinn, 2018). After the initial creation of the content, which is not a trivial effort, the content in adaptive learning systems must be maintained and reviewed for accuracy. Hiring staff to support adaptive learning systems, as seen in the UCF account, is criticized as contributing to "administrative bloat" where higher education non-instructional staff hires have outpaced instructional staff, leading to the increased cost of higher education (Simon, 2017).

Improving quality.

Higher education has been facing calls from accrediting agencies, governments, media, and parents for improvements to the quality of higher education for many years, but what does quality mean (Immerwahr et al., 2008; Schindler, Puls-Elvidge, Welzant, & Crawford, 2015)? In manufacturing, quality means products free of defects; in business it means the degree to which a product meets customer expectations. But in the context of higher education, quality appears to have no standard definition ("Quality," 2019; Schindler et al., 2015). Higher education has failed to reach a consensus for defining quality for years, but the excuse that it is indefinable may no longer be acceptable (Schindler et al., 2015). Increasing scrutiny of higher education now requires institutions to be able to provide evidence to support claims about quality in justifications over the cost of higher education, leading to the development of measures and assessments of quality (Schindler et al., 2015). Improving quality in U.S. higher education has grown to mean producing a measurably better learning experience using variables such as

student engagement, persistence, and outcomes, as seen in the UCF account (Immerwahr et al., 2008; Newman et al., 2013).

Driver: quality measure.

The inherent reliance on data and analytics to function means that adaptive learning systems offer the ability to evaluate several quality measures natively. Adaptive learning has also shown the ability to improve these measures at institutions where it is used (J. King & South, 2017; Murray & Pérez, 2015; Newman et al., 2016). Examples of data measures and conclusions in adaptive learning systems include:

- *Time-to-Learn*: OLI and Carnegie Mellon University found that learners who used adaptive learning in half in-person and half adaptive courses had comparable or better learning gains than those in fully in-person courses and took 25% less time to learn the same outcomes (Bowen, Chingos, Lack, & Nygren, 2014)
- *Student Engagement*: The University of Central Florida found that 83% of learners reported that the adaptive learning system Realizeit helped them learn better (Johanes & Lagerstrom, 2017)
- *Passing Rates*: Pass rates increased by 18% and withdrawals decreased by 47% in classes using Knewton's adaptive learning system at Arizona State University (Newman et al., 2013)

UCF's use of student engagement measures to justify the expansion of adaptive learning stands out as one practical use of quality measures. Additionally, UCF's measures mean that there is data that the institution can publish to show a better learning experience to the satisfaction of calls for quality assurance in higher education.

Criticism: managerial control of faculty and curriculum.

An underlying criticism of adaptive learning and other education technologies relates to a perceived tradeoff between improving quality and a loss of control: both faculty control over the curriculum and the control an institutional administration has over faculty. It is listed as a "perception" because the loss of control is stated as a criticism in several articles, but there are no studies that show an empirical loss of control due to adaptive learning—only references to the change such as in the UCF account. Still, perceptions from faculty can sway the success of adaptive learning, so this criticism is significant despite its lack of concrete proof.

Slaughter cites that through academic capitalism "universities expand managerial capacity to monitor, incent, and discipline the increasingly differentiated faculty" (Slaughter, 2014, p. 13). The data in adaptive learning can be used for purposes of control wherein faculty effectiveness can be inferred from individual course quality measures, such as passing rates, in more detail than ever before. Historically, curricular control has rested on the faculty. Adaptive learning can be seen as a new form of teacher-proofing to standardize instruction across instructors and creep into the freedoms faculty traditionally have held. Slaughter and Rhoades (2004) projected that "the ascendance of the academic capitalist knowledge/learning regime requires us to rethink the centrality and dominance of the academic profession" (pg. 10).

We come back to the widely cited article From Sage on the Stage to Guide on the Side (1993), which states that the role of the instructor was to facilitate learning in "less directive ways" in personalized instruction (King, 1993, p.30). In the use of adaptive learning, some instructors simply do not want to cede curricular control to technology, nor do they want their learners to lose control either (Johanes & Lagerstrom, 2017). One person described the technology as:

> Adaptive learning, as I understand it, turns learning into a program we navigate, the software telling us what we need every step of the way. We wait for the software to tell us what's next. It removes agency from the equation, telling us what we "need," rather than letting the individual ask and then answer their own questions. (Warner, 2013, para. 16)

For those critical of adaptive learning, there exists a possibility that focusing on the measures reduces the focus on actual learning. "Let's stop pretending that any of this has to do with concern about learning. This is business" (Warner, 2013, para. 21).

Increasing access.

A principal driver for the use of adaptive learning in higher education is its ability to make higher education more accessible to a wider range of learners. Access means giving all those who would like a chance at an advanced education the opportunity to pursue it (Immerwahr et al., 2008). Like UCF and ALMAP, several initial explorations into the use of adaptive learning in the adaptive learning movement centered on expanding access to underserved populations (Dziuban et al., 2016; Newman et al., 2013). While there has been a mix of conclusions over the effectiveness of adaptive learning, access continues to be the most widely referenced reason for its use.

The terms access and accessibility are often used interchangeably in higher education, but a cursory view of the two terms finds that *access* is typically associated with the ability to reach a higher education, while *accessibility* tends to mean making educational content and the physical structures of higher education accessible to all persons, typically those who have disabilities (Seale, 2006). While the accessibility of content is indeed an issue that needs to be addressed in

adaptive learning, access is the noteworthy topic in a discussion of academic capitalism and adaptive learning.

The access discussion of adaptive learning and academic capitalism has two significant parts. One is in the use of adaptive learning for expanding the reach of higher education to a wider range of learners for the purpose of the greater good; the other is its use in expanding higher education for the purpose of academic capitalism, such as increasing the number of learners to gain more money in tuition or to use adaptive learning to maximize faculty instruction time. The driver is for greater access to education in service of the public good knowledge/learning regime and the criticisms are those that come from the academic capitalist knowledge/learning regime.

Driver: improving access to education.

Virtually all of the major studies on the use of adaptive learning cite access as being a primary driver for the use of adaptive learning (B. Chen et al., 2017; Dziuban et al., 2016; Johanes & Lagerstrom, 2017; Murray & Pérez, 2015; Newman et al., 2013; Shelle, Earnesty, Pilkenton, & Powell, 2018). The 2013 report at the start of the adaptive learning movement on the ALMAP project by Tyton partners, which many institutions used to base their initial interests in adaptive learning, stated that adaptive learning "holds out the promise of increasing access" (Newman et al., 2013, p. 5). In their follow-up report on the state of adaptive learning in 2016, Tyton partners reference the supplier landscape, which boasts about their ability to increase access (Newman et al., 2016). This report prompted UCF to look at adaptive learning as a means to increase access to higher education, which they followed through on (Dziuban et al., 2016).

More recently, the U.S. government referenced the use of adaptive learning to provide greater access to higher education. The 2017 National Education Technology Plan (NETP)

released by the U.S. Department of Education highly endorsed the use of adaptive learning for access (J. King & South, 2017; Lynch, 2017). *Reimagining the Role of Technology in Higher Education: A Supplement to the National* Education *Technology Plan* conceptualizes a change to higher education through innovation, specifically personalized learning technologies like adaptive learning (J. King & South, 2017). The NETP states:

> By placing students at the center, we can frame our understanding and design of programs, course offerings, and institutions based on their attributes and needs. In this way, our institutional policies and practices can better help students overcome barriers to successful completion. In addition, we can expand our ability to provide higher education opportunities for a greater number of students, with a broader range of needs, at a lower cost (J. King & South, 2017, p. 6).

The use of adaptive learning for improving access to higher education appears to be a topic of greater interest for public institutions, such as the institutions participating in the APLU ALMAP project and UCF, than to private ones. This is most likely due to the difference in institutional missions regarding their role in regional economic developments. Public institutions are typically governed and funded by interests in the public good, whether it is state governments or local leaders, and increasing access serves the public good.

One standout private research institution using adaptive learning to increase access to higher education is Carnegie Mellon University in their OLI project (Elizabeth Jeffries, 2015). One of the OLI project's goals is to use technology to aid underserved populations (Walsh, 2010). However, the difference in public versus private institution interest in adaptive learning requires additional research.

Criticism: neoliberal values.

A criticism of the use of adaptive learning for increasing access in higher education is that the motivation behind increasing access is tailored to promote neoliberal values and behaviors under the guise of doing so for the public good (Kerr, 2014). In essence, there is concern that increasing access to higher education is being driven by market-like activities, such as the need to increase revenues or promote quality assurance measures, instead of providing an education to underserved populations or promoting education for the benefit of society. Adaptive learning is then seen as a tool which promotes these market-like activities and does not have the best interest of learners or faculty in mind. Instructor, lecturer, and course materials writer Philip Kerr states:

> The drive towards adaptive learning is being fueled less by individual learners or teachers than it is by commercial interests, large educational institutions and even larger agencies, including national governments. How one feels about adaptive learning is likely to be shaped by one's beliefs about how education should be managed. (Kerr, 2014, para. 1)

The belief that adaptive learning serves neoliberal values of institutions is supported by examples where the benefits of adaptive learning are overshadowed by discussions on efficiencies, resource allocations, and other market-driven considerations. For example, UCF's use of Realizeit is seeing some pushback for its use in a program to "reduce seat times" as a response to increasing enrollments (Lieberman, 2018; Martin, 2018). In Fall 2018, UCF's business college moved to a course structure where, instead of attending large classes with lectures, students use the adaptive learning system and only meet with instructors a handful of times in the semester (Martin, 2018). The business college placed about 1,200 students in each new format course, which drew the ire of learners, alumni, and their families (Martin, 2019).

The reason for the change cited by administrators focused on economic reasons for making the change. One explanation for the change to more online courses read:

> Paul Jarley, dean of the business college, said he'd need 72 additional instructors in order to teach all of those courses in lecture settings with 120 students in each class. And he doesn't have enough classroom space to accommodate all those new course sections, either. (Martin, 2018, para. 5)

While some explanations did tout the benefits of the course change, such as personalized learning, the learners did not see the value, with one student stating "I just do not like the format. I think we're going to be scammed out of our money" (Martin, 2018, para. 24). Others saw it as "onerous and not conducive to learning" (Lieberman, 2018, para. 1).

Another criticism tied to increasing access and neoliberal values originates from concern over the use of educational technology as a step towards the free-market oversight of higher education (Abendroth & Porfilio, 2015; Veletsianos & Moe, 2017). In conversations over the use of educational technology, adaptive learning is just the latest use of technology as a neoliberal solution for educational problems (Abendroth & Porfilio, 2015). To some, educational technology "represents efforts to design, develop, and use technology to achieve a never-ending array of desirable educational outcomes, including improving learning, increasing retention rates, enhancing teaching effectiveness, reducing costs, and increasing access" (Veletsianos & Moe, 2017, para. 1). They see adaptive learning as a tool for the neoliberal restructuring of education, replacing principal forms of pedagogy with the "Netflixing" of learner development (Roberts-Mahoney, Means, & Garrison, 2016; Slater & Seawright, 2018), meaning:

> Just as many major corporations such as Netflix, Google, Amazon, and others rely on the adaptive and responsive digital technological platforms, advocates of personalized learning push for the utilization of algorithmic programs, computer adaptive testing, and other data driven and collecting systems that, they claim, efficiently enhance student learning by precisely tailoring educational processes—replacing engaged forms of pedagogy—to the skills and needs of students. (Slater & Seawright, 2018, p. 379)

As with the companies that utilize personalized learning to monitor, measure, and value their businesses, some see adaptive learning as the changing of education towards utilizing these same market-like values, which is a cause for ardent criticism.

What do these drivers and criticisms mean for the future of adaptive learning? The final chapter attempts to take the lessons learned from history and both sides of the argument to project future trends in adaptive learning.

CHAPTER 6

A Future of Ongoing Dilemmas for Adaptive Learning

Adaptive learning is not the simple, seemingly successful, solution it initially appears to be. In fact, there is such an abundance of complicating factors, such as the influence of academic capitalism and actors driving or criticizing its use, that a cursory attempt to anticipate the future of adaptive learning brings higher education to a set of dilemmas with very few answers. This chapter outlines a few of these dilemmas and problems in adaptive learning that require ongoing consideration, as they almost certainly will affect the future of adaptive learning in higher education and at individual institutions. It follows a similar question and answer narrative format used by Ramesh Srinivasan (2019) in his book on innovation, *Beyond the Valley: How Innovators around the World are Overcoming Inequality and Creating the Technologies of Tomorrow*. As stated in the introduction, the goal of this study is to aid in decision-making about adaptive learning, and this chapter serves as a guide towards an understanding of adaptive learning without offering over-simplified solutions to an otherwise complex issue.

Academic Capitalism

Can higher education recognize the problems presented by academic capitalism? It is not difficult to recognize the influence academic capitalism had, and continues to have, on the development of adaptive learning. The market and market-like activities of higher education have guided the foundations and features of this innovation and have created an environment where adaptive learning is a worthwhile solution to the issues of cost, quality, and access. To the development and ongoing prospects for adaptive learning, academic capitalism has had an overall positive effect. However, for higher education, and the desire to adhere to the traditional public good knowledge/learning regime, academic capitalism is problematic (Slaughter &

Rhoades, 2004). The same factors that have made adaptive learning possible have eroded decades of valued practice, such as the shift from smaller classes to larger ones to accommodate a growth in enrollment and offset resource shortcomings. In this case, adaptive learning becomes a valuable tool to reach these additional learners, but the institutional problems from this shift, such as the need for more courses and instructional designers to support them, are often an afterthought.

Recognition of the problems stemming from academic capitalism is happening in the individual criticisms of adaptive learning, as detailed in the previous chapter, but the problems are being attributed to the innovation and not the factors which have made it possible, which are the market and market-like behaviors of institutions. The dilemma becomes whether to address the root cause, academic capitalism, or focus on individual problems stemming from an outcome of academic capitalism, such as adaptive learning or massification. Targeting individual problems may not stop the flow of issues from academic capitalism, but it may be more fruitful than addressing the cultural shift in higher education towards academic capitalism.

A Place for Adaptive Learning

Is it possible for critics to find a place for adaptive learning? Unless mandated by an institution, which is highly unlikely at either private or public research institutions, the adoption of adaptive learning by individual faculty members at higher education institutions will never reach one hundred percent. Those critical of adaptive learning will, in all likelihood, never be required to use an adaptive system. That being said, while they may not be required, it may be possible to sway critics of adaptive learning to utilize the system if the benefits outweigh the disadvantages or their personal criticisms. For example, critics of the use of adaptive learning due to its contributions to massification may look into using adaptive learning if their course load

becomes unmanageable or if their interest in the social justice aspect of increasing access outweighs their criticism of the innovation's contributions to massification. Additionally, academic capitalism may be a desired group of behaviors if the alternative is in some way entirely negative. If departments were to find themselves in the same situation as many small private colleges that are fighting to remain open, and market, or market-like, behaviors are the only remaining option, then the critics may find the desire to use products that support academic capitalism such as they believe adaptive learning does (Marcus, 2019).

Are there limits to the use of adaptive learning? While additional study is needed, UCF may have inadvertently found a limit to the proliferation of adaptive learning at their institution as exposed from the recent pushback against the "mandatory reduced-seating format" implemented in Fall 2018 by their College of Business (Adeyemo, 2018). Detailed in the earlier adaptive learning account at UCF, tensions flared when their adaptive learning system, Realizeit, was employed to offset resource constraints by mandating more online learning and less in-person courses. While the direct cause of the pushback could be one or a combination of many causes, such as its mandatory status, the loss of contact with faculty or socialization, or the use of the system with "glitches", there does appear to be hint of a limit to the use of adaptive learning. The dilemma is whether an institution places a preemptive limit on its use or whether it moves forward with adaptive learning until a limit is reached.

Educational Technology

Is adaptive learning less about the technology and more about the goals and practices of higher education? This study suggests that adaptive learning is indeed more about the goals and practices of higher education than the technology. Adaptive learning is not a singular technology, such as an iPhone or Microsoft Word, but a collection of systems that all adhere to

the proposed definition of being adaptive (Pugliese, 2016). Each of these systems, such as Realizeit and Coursera, rely on proprietary algorithms to digest information and display content while offering various technological features, like pre-designed courses or interactive communications, but the differences between these individual systems are almost irrelevant as they all rely on the goals and practices of individual institutions who use their products. This is why the focus on academic capitalism is critical. Academic capitalism is the main source for drivers and criticisms of adaptive learning, and a primary driver in the ongoing development of individual systems. Companies like Realizeit rely on information gathered in their relationships with higher education institutions to develop their products, using higher education institutions as testing grounds (Howlin & Lynch, 2014). Via this relationship, the needs of the higher education institutions become the features of adaptive learning systems, analogous to the theory of the social construction of technology (Janet & Yuan, 2017). The drivers behind the needs of higher education are then reflected in the development of adaptive learning, meaning that these drivers become more important than the technology itself. Additionally, deciding on which adaptive learning system to use comes down to how the system fits in and contributes to the goals and practices of individual institutions, instead of tailoring the goals and practices to those of the individual technology, which may lead to a wider set of problems.

How important is institutionalization on the success of adaptive learning? In the account of UCF's use of adaptive learning, UCF focused on access as the primary driver and justification for the adoption of the adaptive learning system Realizeit. The decision that access would be the primary reason to use it, along with the work completed to make the adaptive learning practical at UCF, is part of the institutionalization process for adaptive learning (Vargo et al., 2015). It means shaping the innovation to work in a particular environment, as well as making changes to

the environment to make the innovation successful. During the institutionalization of the adaptive learning, actors at UCF, guided by insights from their own institution and higher education, molded both the institution and the innovation to make it part of their organization's culture. UCF faculty, staff, and administrators chose which courses to start with, how the adaptive learning system would be used by faculty and students, and how much money they would spend, also including decisions on a multitude of other variables, that eventually led to how adaptive learning took shape at UCF. The institutionalization of adaptive learning at UCF was one of, if not the largest contributing factor to its success. Had they chosen to focus on cost, or to minimize the number of courses it would be used in, then the outcome of their adaptive learning use would have been much different. This institutionalization process is unique to each institution and holds the key to the success of adaptive learning in higher education. It is driven by higher education administrators, faculty, and staff, and is one important reason these actors should have a complete understanding of adaptive learning and their own institutions before embarking on its use.

The Future of Work

How will the Fourth Industrial Revolution (4IR) affect adaptive learning? Klaus Schwab, Founder and Executive Chairman of the World Economic Forum, contends that what we are witnessing is the "beginning of a revolution that is fundamentally changing the way we live, work, and relate to one another" (Schwab, 2016, p. 1), called the Fourth Industrial Revolution (4IR). The 4IR is characterized by a blurring of the physical, digital, and biological worlds occurring at a great rate of speed and over a global scope, resulting in the innovation of technologies, products, and operating models never witnessed before (Schwab, 2016). The 4IR has stimulated innovations in artificial intelligence, robotics, genetic engineering, and quantum

computing, some of which have had a direct impact on the development of adaptive learning. Should higher education move toward preparing learners to work in the 4IR, or does it continue unwavering from the well-rounded traditional preparation of learners?

The utilitarian perspective argues that higher education institutions should prepare learners to meet the workforce needs of society and participate in the global economy (Spellings, 2006). Set against profound shifts across industries, the emergence of new business models, and the disruption of incumbent businesses, the utilitarian perspective appears to hold an upper hand over the classical perspective in that it aligns closer with the needs of the changing global economy (Schwab, 2016). While the question over the purpose of higher education remains unanswered, and is perhaps destined to remain so, higher education's role in the success of the national economy cannot be ignored. Many of the current criticisms and drivers of adaptive learning, such as the utilitarian perspective, are guided by the market and market-like behaviors of higher education institutions. With that in mind, the future of adaptive learning will, in part, be shaped by changes in the global economy, the future of work, and the ongoing participation of higher education in contributing to the workforce and academic capitalism. Understanding the global environment is critical for gauging where adaptive learning may prove beneficial or problematic to higher education.

Does adaptive learning seek to replace faculty via automation? Klaus Schwab (2016) identifies one certainty from the impact of the new technology revolution: "new technologies will dramatically change the nature of work across all industries and occupations" (p.35). This certainty is in regards to the negative impacts of technology on the labor market, particularly automation, in the 4IR. There is a notable distinction between the changing nature of work and changes in employment, or jobs. Work is the processes and practices used to complete the

responsibilities of employment. There will be significant changes in both work and employment in the 4IR.

First, there will be large changes to employment. Some workers will be displaced by technology, where their jobs will go away entirely, while other employment opportunities will be created due to advances in automation technology in the 4IR (Schwab, 2016). Schwab offers this description:

> We have to understand the two competing effects that technology exercises on employment. First, there is a destruction effect as technology-fueled disruption and automation substitute for capital labor, forcing workers to become unemployed or to reallocate their skills elsewhere. Second, this destruction effect is accompanied by a capitalization effect in which the demand for new goods and services increases and leads to the creation of new occupations, business and even industries. (Schwab, 2016, p. 37)

Frey and Osborne (2017), who Schwab cites as having quantified the potential effect of technical innovation on employment, found that the probability of postsecondary instructors being automated is very low, at 0.032 (Schwab, 2016). From that, the likelihood that the position of higher education faculty will face a "destruction effect" should not be a large concern. Fears that adaptive learning is changing the faculty jobs in higher education can trace some of their roots back to the fear of technology replacing instructors. Based on the history of teaching machines, specifically Pressey versus Skinner, this fear is not unfounded, but it is continuously dispelled as a myth (Dutton, 2018). Faculty are wholly necessary for the future of adaptive learning and there is no general driver for adaptive learning to replace instructors (Dziuban et al., 2016; Vignare et al., 2018).

Second, there is some inevitability that the work faculty undertake to do their jobs will change. It has certainly changed since the start of the knowledge economy, with the development of the internet and resulting innovations in communications technology, like email and online learning, adding new processes and practices to the everyday work of faculty. The future of faculty work will be determined by the eventual outcome of the effects of the 4IR and automation on higher education and the workforce. Adaptive learning is just one more way automation may change the work of faculty, but it, so far, does not seek to replace faculty.

Learners

Where do the learners fit in this discussion on adaptive learning? Studies on adaptive learning lack fruitful insights into the learners' perceptions, feedback, and outcomes in higher education (Johanes & Lagerstrom, 2017). UCF offers some of the first insights into learner data, but researchers there acknowledge that more studies on learner interactions should be conducted (Dziuban, Moskal, et al., 2017). I had hoped to survey students for their impressions of adaptive learning, but that proved to be substantial undertaking that could be better served by a targeted study on learners. I do not believe that lack of learner information is a significant limitation to this study due to its focus on academic capitalism, but future studies, and especially the future success of adaptive learning, hinge on understanding the role and future of learners in adaptive learning. Where learners fit in discussions on adaptive learning requires additional study.

CONCLUSION

Adaptive learning as an innovation in higher education remains in a constant state of flux. Ongoing technological developments and new adoptions at higher education institutions continue to stimulate changes to adaptive learning products, build new use cases, and spark new criticisms and drivers for adaptive learning across higher education. This study highlights the ways in which the sociocultural environment, heavily influenced by academic capitalism and the knowledge economy, has been and continues to be a major factor in the development and propagation of adaptive learning across higher education and at individual institutions.

The history of adaptive learning demonstrates how the macro environment, the global economic environment that commodified knowledge, set into motion the ongoing development of an idea for personalized learning into the practical use of adaptive learning across higher education. While there were instances of the use of adaptive learning prior to the knowledge economy, such as PLATO and ITS, it wasn't until the onset of knowledge economy and the maturation of foundational technologies, such as online learning and MOOCs, that use of adaptive learning began to grow. Now firmly in the adaptive learning movement, the drivers and criticisms rooted in academic capitalism hold sway over the ongoing institutionalization of adaptive learning as an innovation in higher education and at individual institutions.

This study breaks away from trends in the academic capitalist knowledge/learning regime to provide information about adaptive learning for the public good. The future of adaptive learning is in the hands of key actors who will need to work through challenges and dilemmas to determine if and how adaptive learning becomes institutionalized in higher education. Administrators, faculty, and staff have need of this critical study to guide decision making if the hope of breaking through the Iron Triangle of Education via adaptive learning is to be realized.

Significance of This Study

The story of adaptive learning is long and complicated, more so because it is ongoing. With every new study or article on adaptive learning, and with every new use and the knowledge garnered from it, the story of adaptive learning becomes richer, but not necessarily clearer. This study, as a narrative account of adaptive learning, is aimed at faculty, staff, and administrators in higher education who would like to reach this clearer picture of adaptive learning. It brings together information from governments, administrators, researchers, faculty, and technologists at an opportune time to be able to question the use and proliferation of adaptive learning in higher education at the department, institution, or broad higher education level. This study is well-timed, when adaptive learning is taking root in higher education and when the technology is becoming cheaper and more effective. There are new articles published regularly on adaptive learning in higher education and ongoing questions on where adaptive learning may be impacting higher education (Alexander et al., 2019). My hope is that this study informs the appropriate actor's decision-making toward the consideration/discounting of adaptive learning, or at minimum, raises questions about the use of adaptive learning at individual institutions.

Implications

Insights into the history, current use, and the future outlook of adaptive learning from this study pose a few implications to the theory and practice of higher education. First, the theory of academic capitalism directly influences practice. Academic capitalism, as both an underlying driver for innovation in higher education and a source for criticism against it, plays a much larger role in decision-making about educational technology than is widely cited. The clarity seen by which academic capitalism affects the progress and outlook of adaptive learning should give

higher education actors pause enough to consider academic capitalism as an important variable in educational technology decision-making, and quite possibly other areas of higher education.

Second, while this study focuses on adaptive learning on higher education, higher education is only one part of the system of education. The implication of this is that, while there is a movement to increase the use of adaptive learning in higher education, other areas of education, such as K-12 or continuing education, are also experiencing some form of pressure to address similar ongoing issues like cost and quality. The criticisms surrounding the traditional practices of all of education are prompting changes that should be viewed and studied as a whole system of education, rather than one part of it such as higher education. The use of adaptive learning, and other educational technology, may have far-reaching impacts across the system of education that may be missed if only viewed in parts.

Third, the implementation of adaptive learning requires that content be simplified, or broken down into smaller interconnected elements, which means that only subjects that can be expanded into their individual elements may be viable targets for the use of adaptive learning (Moskal et al., 2017). For example, math subjects, which are already collections of smaller interconnected elements that build on one another, are better suited for adaptive learning than creative or complex subjects such as writing or philosophy. This study did not address the content limitations of adaptive learning, but the practical use of adaptive learning across all subjects may not be possible. The subject limitations of adaptive learning require additional study.

Finally, there is some concern that adaptive learning may not adequately prepare learners for success in 21st century society and workplaces. As highlighted in this study, the rising demand for a highly skilled workforce in the knowledge economy and the 4IR has prompted a

shift in higher education toward supplying learners to meet this demand. The use of innovations such as adaptive learning grew from this demand, but the question remains whether the knowledge and skills learners are gaining through these innovations are indeed the knowledge and skills needed to succeed in this new workplace and if they are prepared to flourish in this 21st century society. The development of 21st century skills is seen as the key to learner success in the new workplace and society (Trilling & Fadel, 2009). These skills include: critical thinking and problem solving, creativity and innovation, digital literacy skills, flexibility and adaptability, social and cross-cultural interaction, and many others (Trilling & Fadel, 2009). Studies on the ability for adaptive learning to help learners develop these 21st century skills remain scant. If adaptive learning is unable to assist learners develop these skills, does adaptive learning continue to be a promising innovation for higher education?

Closing Thoughts

This study generalized the innovation of adaptive learning as one technology, akin to a single program like Microsoft Word, to make it easier to study, when in fact adaptive learning can be a wide range of programs, be as small or as large as a single course or hundreds of courses, or be as simple or complicated as buying off-the-shelf or building your own instances. What has become increasingly apparent is that the future of adaptive learning is in the hands of higher education faculty, staff, and administrators, all in some way impacted by academic capitalism. Advancements in the technology of adaptive learning are less of a consideration in its success than the choice of higher education institutions to use adaptive learning and to work through the institutionalization of the innovation (Pugliese, 2016). This means that no matter how powerful or effective adaptive learning technologies become, the key to its advancement is an issue of aligning with institutional goals and the appeal to individual actors at higher

education institutions. For institutions like UCF, whose mission includes expanding higher education access and who were willing to make large-scale institutional changes, adaptive learning is an ideal choice. Other institutions that adhere to traditional practices and who do not have the capital or desire to change institutional practices would, in all likelihood, not find adaptive learning desirable. In the end, adaptive learning is not the "disruptive innovation" to higher education that some assume was coming with impunity and destined to change the future of higher education (C. M. Christensen, Horn, Caldera, & Soares, 2011). Higher education institutions and individual actors are the gatekeepers who determine if adaptive learning is to proliferate. They must be open to change and work through the dilemmas of institutionalization for adaptive learning to ever make a significant impact on higher education. Until then, adaptive learning remains an innovation full of promise making its way through the ebb and flow of higher education.

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