Assessing design quality in online courses at a public university

Anthony Kiech

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ASSESSING DESIGN QUALITY IN ONLINE COURSES AT A PUBLIC UNIVERSITY

by

Anthony E. Kiech

A Dissertation
Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Education

Major: Instruction and Curriculum Leadership

The University of Memphis

May 2024
Dedication

To my wife, Jaime, and our precious children, Asher, Alexandria, and Zeke, this work is not a product of my solitary efforts but a testament to your patience, sacrifice, and love. Your tireless support, understanding, and encouragement have been the foundation for this work. This is a collective achievement. Thank you, and I love you all dearly.

I also thank my dissertation committee and the wonderful faculty who helped me on this journey. I am forever grateful for your support.
Abstract

This research assesses the extent to which asynchronous online STEM courses at a public university integrate Merrill's First Principles of Instruction. Through a quantitative content analysis of thirty unique online courses within the College of Arts and Sciences, the study investigates the extent, if any, to which these courses embody principles such as problem-centered learning, activation, demonstration, application, and integration. A validated survey instrument, Course Scan, was used for evaluation and indicated a low extent of Merrill's First Principles of Instruction in the sample courses. Methodology, including the investigation plan and instrumentation, are shared. Results are shared, indicating low implementation of First Principles in sample courses, as well as a breakdown of each individual principle. Results are discussed, including implications for practice through improving design quality at the university and implications for the field of online course design in higher education.

Keywords: Online course design, public university, course design quality evaluation methodologies, problem-centered learning strategies, activation learning strategies, demonstration learning strategies, application learning strategies, integration learning strategies.
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<tr>
<td>ARCS</td>
<td>Attention, Relevance, Confidence and Satisfaction model of motivation</td>
</tr>
<tr>
<td>CAS</td>
<td>College of Arts and Sciences</td>
</tr>
<tr>
<td>ERP</td>
<td>Enterprise Resource Planning</td>
</tr>
<tr>
<td>FPI</td>
<td>First Principles of Instruction</td>
</tr>
<tr>
<td>IRB</td>
<td>Institutional Review Board</td>
</tr>
<tr>
<td>LMS</td>
<td>Learning Management System</td>
</tr>
<tr>
<td>MOOC</td>
<td>Massive Open Online Courses</td>
</tr>
<tr>
<td>NGSS</td>
<td>Next Generation Science Standards</td>
</tr>
<tr>
<td>PBL</td>
<td>Problem-Based Learning</td>
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<tr>
<td>STEM</td>
<td>Science, Technology, Engineering, and Mathematics</td>
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<tr>
<td>SME</td>
<td>Subject-Matter Expert</td>
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CHAPTER ONE: INTRODUCTION

The growth in demand for online courses has been increasing for decades and has been expedited recently by the COVID-19 pandemic (Trust & Whalen, 2020). Furthermore, adult learners have become increasingly interested in online learning, given their desire for increased flexibility and alternative options to assist with the balance of education, family, and work responsibilities (Hsieh, 2020; Pratama et al., 2020). Therefore, in order to remain competitive and attract students, universities have sought to improve the quality of asynchronous and synchronous online courses and programs (Guerrero et al., 2021; Marasi et al., 2022). For the purpose of this research, asynchronous online course delivery modalities refer to instructional methods in which learners access course materials and activities on their own schedule without required real-time interactive sessions. In contrast, synchronous online course delivery modalities describe instructional methods that require simultaneous participation, often through live video conferencing, webinars, or real-time chat forums.

To develop effective and quality online courses and programs, it is critical to expertly apply instructional design principles. According to Merrill (2013, 2020), correctly utilized designs can enhance student learning and confidence. Cassidy (2014) and Judson et al. (2008) found improved course design retention rates of students and student enrollment numbers, as well as positive reviews of universities’ online programs. Numerous methods can be utilized to measure course design quality for online courses; some of these measures focused on learners’ experiences, while other studies have explored instructional design quality (Baldwin et al., 2018). Unfortunately, there currently is no single framework to define or standardize this notion of quality design,
although several concepts have been proposed (Hsieh, 2020; Rosser et al., 2003). There is no recognized measurement tool to assess the quality of online course designs (Observatory on Borderless Higher Education (OBHE), 2013).

Universities often struggle to identify frameworks with which to assess quality, and many institutions develop locally created assessments that may or may not be grounded in research and theory (Baldwin & Ching, 2019). When universities develop individual assessments, both the validity and reliability of the assessment are unknown. When this occurs, effectiveness and quality may not be accurately determined, and incorrect decisions about course improvements may ensue (Tuah & Naing, 2021). Additionally, without a recognized measurement tool to assess the quality of online courses, students may have wildly varied experiences, with some receiving exemplarily designed learning experiences while others face dismal learning opportunities. Consequently, student learning outcomes, success, and equity to achieve rigorous standards may be undermined.

**Problem of Practice Statement**

The university administration and instructional designers at one public university in the southeastern United States of America desired to identify strengths and weaknesses in online course design. They used a university-developed, unvalidated assessment to determine the quality and effectiveness of online course design. Results from this evaluation were crucial as they empowered instructional designers and administrators to make informed, data-driven decisions regarding necessary improvements and resource allocation to enhance online course design quality. However, the tool lacked validation against established standards, which may have led to potential inaccuracies in
representing the actual quality of this university’s online course design, as highlighted by previous research (Baldwin & Ching, 2019; Lee et al., 2020; Zimmerman et al., 2020). There is an absence of evidence indicating that a quantitative content analysis using a validated tool has been previously conducted. Therefore, a valid and reliable framework was needed to assess the courses.

Merrill’s First Principles of Instruction is a longstanding and well-researched theory that developed core principles to provide a framework for engaging and effective learning (Merrill, 2013). As such, this theoretical framework proved to be an excellent foundation upon which university administrators and instructional designers could determine if the current online course design quality at the university met standardized quality online design objectives or if and how course designs needed to be improved. Margaryan (2008, 2015) suggested that without intentional and directed resources and assistance, individual faculty members independently designing online courses would likely omit most of Merrill’s First Principles of Instruction to a great extent.

Evaluating the design quality of the university’s online courses with a theoretically grounded and validated tool can help identify strengths and weaknesses of course design across disciplines, levels, and semester types. The results of such an evaluation could allow instructional designers and administrators to make timely, data-driven decisions about course improvements, resource allocations, and necessary actions (Margaryan et al., 2015). Improvements to online course design can result in more robust programs and better student outcomes; both of which align with the university’s mission. Given this trend in which many universities, including the university selected for this study, use internally-created evaluation metrics to gauge the quality of online courses,
even though these rubrics are rarely validated against accepted standards, it is imperative
for a more standardized means for evaluation to be developed and implemented so that
course evaluations may be accurate representations of online course design quality
(Baldwin & Ching, 2019; Lee et al., 2020; Zimmerman et al., 2020).

**Purpose Statement**

This quantitative, content analysis aimed to establish the extent, if at all, to which
asynchronous online STEM courses designed at the university employ the First principles
of instruction. The university offered 53 unique online courses in STEM disciplines
during the academic year of 2022-2023 in the College of Arts and Sciences (CAS). Three
experienced coders rated a majority sample, which included thirty of the 53 offered
courses using Course Scan, an instrument to assess the extent of Merrill’s first principals
of instruction. Prior to rating, coders underwent a pilot review to ensure the reliability of
ratings; interrater reliability analyses were also conducted to verify the consistency of
ratings. The extent to which the five fundamental principles were present is reported, as
determined by the Course Scan First Principles of Instruction evaluation instrument
(Margaryan et al., 2015). The research methodology, findings, and analysis methods are
presented and discussed in chapter 3, but first, an understanding of this study’s theoretical
framework is necessary.

**Theoretical Framework**

Merrill’s First Principles of Instruction was chosen as an effective framework to
determine the quality of online course designs at the university and explore instructional
design conditions. Merrill’s First Principles of Instruction is a sequence of interconnected
standards for instruction derived from leading instructional design theories and models
(Merrill, 2002a). First introduced by Merrill in 2002, the First Principles have had comprehensive development, analysis, and validation over approximately twenty years (Badali et al., 2020; Margaryan & Collis, 2005; Merrill, 2013). The First Principles of Instruction included five principles: problem-centered, activation, demonstration, application, and integration, as seen in Table 1 (Margaryan, 2008; Merrill, 2013). Due to its longevity in literature and extensive research, the First Principles of Instruction was determined to be an appropriate and validated standard to evaluate the design quality of the university’s online courses (Badali et al., 2020; Merrill, 2013).

Table 1

*Merrill’s First Principles of Instruction*

<table>
<thead>
<tr>
<th>First Principles</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Problem-Centered</td>
<td>Learning should be rooted in real-world problems.</td>
</tr>
<tr>
<td>2. Activation</td>
<td>Prior knowledge should be activated before new learning.</td>
</tr>
<tr>
<td>3. Demonstration</td>
<td>New knowledge should be demonstrated to the learner.</td>
</tr>
<tr>
<td>4. Application</td>
<td>Learners should be given the opportunity to apply new knowledge.</td>
</tr>
<tr>
<td>5. Integration</td>
<td>Learners should have opportunities to integrate new knowledge into their lives.</td>
</tr>
</tbody>
</table>

**Research Questions**

In order to provide a robust analysis of this topic, several research questions have been proposed. They are as follows:

Research Question 1. To what extent, if at all, are the College of Arts and Sciences’ asynchronous online STEM courses problem-centered?
Research Question 2. To what extent, if at all, do the College of Arts and Sciences’ asynchronous online STEM courses demonstrate activation of existing experience?

Research Question 3. To what extent, if at all, do the College of Arts and Sciences’ asynchronous online STEM courses reflect the principle of demonstration?

Research Question 4. To what extent, if at all, do the College of Arts and Sciences’ asynchronous online STEM courses enable learners to apply their new knowledge or skill to solve problems?

Research Question 5. To what extent, if at all, do the College of Arts and Sciences’ asynchronous online STEM courses encourage learners to integrate new knowledge or skill?

Research Question 6. To what extent, if at all, does the design of the College of Arts and Sciences’ asynchronous online STEM courses reflect the First Principles of Instruction?
Definitions

**Asynchronous Online Courses.** Asynchronous online courses are courses that do not require real-time interaction. Students can access course materials, participate in discussions, and complete assignments at their own pace within set deadlines (Swan, 2001).

**Course Scan Evaluation Instrument.** The Course Scan First Principles of Instruction Evaluation Instrument is a tool deployed to evaluate the degree to which an instructional element, such as a course, aligns with Merrill’s First Principles of Instruction. Its primary function is to guide the design process toward effective instructional experiences (Margaryan et al., 2015).

**Enrollment Growth.** Enrollment growth refers to an increase in the number of students registering for courses at an institution. As a strategic goal for many universities, it is often influenced by program availability and flexibility, tuition pricing, and the institution’s reputation (Allen & Seaman, 2007).

**Enterprise Resource Planning (ERP).** Software that higher education organizations use to manage aspects of administration such as course offerings, enrollments, accounting, and other business activities (Shaul & Tauber, 2013).

**Instructional Design Principles.** For the purpose of this research, instructional design principles serve as fundamental guidelines derived from learning theories. They are strategically utilized to enhance educational activities, promote effective learning, and facilitate knowledge retention (York & Ertmer, 2016).
**Learning Management System (LMS).** A software tool allowing for the creation, administration, and tracking of learning units such as educational classes or training courses (Simanullang & Rajagukguk, 2020).

**Merrill’s First Principles of Instruction.** Also written as the First Principles of Instruction or First Principles, this pedagogical theory asserts that effective instruction should incorporate five main components: e.g., problem-centered, activation, demonstration, application, and integration criteria; these primary principles form the core of this theory (Merrill, 2013).

**Online Course Design.** Online course design refers to the meticulous process of conceptualizing, producing, and structuring an online course. Elements such as content, learning activities, assessments, technological tools, and provisions for interaction, accessibility, and student support are factored into the design process (Baldwin et al., 2018).

**Online Courses.** Formal educational content delivered primarily via the internet. These courses can be accessed anywhere and anytime and often provide synchronous or asynchronous interactive components for students to engage with the material and with other students (Baldwin et al., 2018). This study focuses on asynchronous online courses.

**Quantitative Content Analysis.** Quantitative content analysis is a research technique aimed at quantifying and scrutinizing the occurrence, interpretations, and interconnections of specific words, themes, or concepts in content (Huxley, 2020).

**Science, Technology, Engineering, and Mathematics (STEM).** For the purpose of this study, asynchronous online courses offered by the College of Arts and Sciences at the university were limited to STEM disciplines, including biological sciences,
chemistry, computer science, engineering, epidemiology, geoscience, physics, and technology. These include all STEM disciplines that are housed in the College of Arts and Sciences and offered courses in an online, asynchronous format during the 2022-2023 academic year.

**Student Success.** In an academic setting, student success is typically perceived as the realization of key educational outcomes. These encompass involvement in significant learning activities, satisfaction with educational experiences, acquisition of desired knowledge and skills, degree completion, and post-graduation accomplishments (Alyahyan & Düştegör, 2020).

**Synchronous Online Courses.** For the purpose of this study, and as defined by the university, a synchronous online course is any online course with required meeting times, either in a specific location or scheduled via a web-conferencing system. Optional meetings would not constitute a synchronous designation.

**The University.** For the purposes of this study, “the university” refers to a medium-sized public institution of higher learning situated in the southeastern region of the United States. It offers a comprehensive range of both undergraduate and graduate programs in traditional in-person and online formats and has a significant local and regional impact, drawing students predominantly from the surrounding region. As a part of its mission, the university is committed to providing quality education, fostering research, and serving the community.
CHAPTER TWO: REVIEW OF THE LITERATURE

Introduction

The landscape of higher education has been transformed by rapid growth in online learning (Bolliger et al., 2014; Herman, 2013). Enrollment in college-level online courses in the United States reached 7.2 million students as of 2020, representing a seven-fold increase since 2012 (Irwin et al., 2021). The COVID-19 pandemic further accelerated the adoption of online learning, with 90% of colleges reporting increased demand for online courses in 2020 (Angode & Ressa, 2021; Copley & Douthett, 2020; Ilangarathna et al., 2022; Walke et al., 2020). This massive shift created an imperative for institutions to ensure quality online courses designed to remain competitive and ensure student success.

High-quality online course design is critical for achieving outcomes that matter to key university stakeholders such as students, faculty, instructional designers, and administrators. For students, well-designed online courses support engagement, comprehension, skill development, and satisfaction (Badali et al., 2020; Bongers, n.d.; Gardner, 2010). Quality design also reduces frustrating technical issues that disrupt learning (Cavignaux-Bros & Cristol, 2020; Muljana & Luo, 2019). Faculty benefit through improved student performance, more efficient course facilitation, and greater work-life balance with flexible online teaching (Bongers, n.d.; Herman, 2012; Zimmerman et al., 2020). High-quality online courses are linked to improved retention and enrollment growth at the administrative level, while poor quality undermines recruitment and student success (Gara & La Porte, 2020; Jaggars & Xu, 2016).

Despite this central role of design quality, there is limited consensus on standards, benchmarks, and methods to systematically evaluate and improve online course design.
A proliferation of internally developed quality assurance rubrics used by universities have been developed; however, these localized measures lack grounding in empirical and theoretical research (Baldwin & Ching, 2019; Blazar & Kraft, 2019; Taylor et al., 2018). The subjectivity of university-created tools can hamper meaningful assessment and progress. In contrast, instructional design frameworks based on validated learning principles offer greater objectivity and meaningful assessment (Baldwin & Ching, 2019; Whale et al., 2014).

While several frameworks exist, Merrill’s First Principles of Instruction is one of the most extensively researched and applied instructional design models (Badali et al., 2020; Margaryan & Collis, 2005; Merrill, 2013). Principles such as centering on real-world problems, activating prior knowledge, demonstrating new skills, as well as promoting practice and integration align closely with established standards of quality course design (Badali et al., 2020; Hixon et al., 2016; Nordhoff, 2003). Despite broad research applying Merrill’s model across learning contexts, few studies have leveraged this framework to evaluate quality within online course design at public universities (Gardner, 2010; Merrill, 2013).

The results of a quantitative analysis of design quality using Merrill’s principles could expose weaknesses and guide improvement initiatives for online learning at universities (Cantabella et al., 2018; Cobos et al., 2019; Strijbos et al., 2006). Findings could help university instructional designers and administrators target resources efficiently based on empirical data. Therefore, this study targeted this gap in the current research as it is a quantitative content analysis of online course design mapped to Merrill’s First Principles of Instruction at one southeastern public university.
Theoretical Context

Origin and Evolution of Merrill’s First Principles of Instruction

Merrill’s First Principles of Instruction have their roots in several foundational learning theories and instructional design models. Models include problem-based learning (PBL), Cognitive load, Gagne’s nine events of instruction, and the attention, relevance, confidence, and satisfaction (ARCS) model of motivation (Margaryan & Collis, 2005; Merrill, 2013). These principles synthesize key elements of learning frameworks to provide guidance for structuring effective instruction (Gardner, 2010; Merrill, 2013).

A primary theoretical basis for Merrill’s model is problem-based learning (PBL), which emphasizes learning organized around solving authentic, complex problems (Cai & Moallem, 2021; Merrill, 2007). Merrill’s problem-centered first principle builds directly on PBL’s tenets since they emphasize the resolution of real-world problems. Hmelo-Silver (2004) found that PBL facilitates a deep learning experience in which students are not just passive recipients of knowledge but are instead active participants in the learning process, engaging in self-directed exploration and solution-finding. This method fosters not only the acquisition of knowledge but also the development of critical thinking and problem-solving skills; both of which are essential competencies in today's rapidly changing world. The concept behind this theory aligns with Merrill's core principle that emphasizes problem-solving challenges. These types of challenges often require designers and instructors to change their implementations based on the situation and context of the class, including limitations surrounding technology, access, or support available (Tawfik, Gish-Lieberman, Gatewood, & Hampton, 2021). The activation
principle relates to this concept, implying that prior knowledge should be used as a foundation for learning that underscores the significance of context and relevance in instruction (Lazonder & Harmsen, 2016; Merrill, 2020; Smith et al., 2022). The same idea informs the basis of Merrill’s models since the practice of demonstration was used as an instructional strategy to reduce the cognitive load in working memory during skill development through application (C.-M. Chen & Wu, 2015; Garrison, 2019).

The ARCS model of motivational design also provides the theoretical grounding for Merrill’s activation principle (Keller, 1987). Attention and relevance components of ARCS, which are sources of motivation, align with activation strategies for engaging learners’ existing experiences and interests (Li & Keller, 2018). Gagne’s nine events of instruction informed sequencing and scaffolding of skills application in Merrill’s principles (Lakshmi et al., 2021; Merrill, 2013). For example, gaining attention through an engaging video introduction, connecting new material to learners’ career goals, or providing examples of problems being worked on to demonstrate a process to activate prior knowledge according to ARCS and Gagne’s models (Faryadi, 2012). Additionally, Merrill’s activation principle incorporates scaffolded practice from simple to complex, aligning with Gagne’s application event (Merrill, 2013).

Since its inception in 2002, Merrill’s First Principles of Instruction model has undergone continual refinement and expansion based on new research. The original 2002 publication defined five core principles: problem-centered learning, activation, demonstration, application, and integration (Merrill, 2002a). Approximately four years later, Merrill revised the model to integrate former students’ feedback, adding elements to emphasize experiential learning cycles (Merrill, 2007).
The next significant evolution incorporated principles of differentiating instruction and promoting engagement through social knowledge construction, yielding the addition of collective knowledge, collaboration, and learner-centered teaching elements in Merrill’s 2009 text (Gardner, 2010; Merrill, 2013). Most recently, emphasis on authentic resources and expert performance feedback emerged from studies on problem-centered learning, resulting in the current framework featuring five interrelated principles (Merrill, 2013).

Some researchers have organized the additional elements that emerged through the evolution of Merrill’s model, including social knowledge construction, differentiated instruction, and use of authentic resources, into five new principles (Margaryan, 2008; Margaryan & Collis, 2005). This expanded the framework to feature ten total principles. However, Merrill argues that the five foundational principles are flexible enough to encompass the newer elements (Merrill, 2020). For example, feedback opportunities align with the application principle, while differentiated instruction and authentic resources connect to the demonstration component (Merrill, 2020). Merrill holds that the five core principles form a concise, interrelated cycle that maintains coherence while dynamically integrating new ideas through its components (Merrill, 2020). His streamlined model focuses on generalized design principles rather than specific implementation tactics. Therefore, the literature contains evidence for both the five underlying principles that can absorb newer insights, as well as ten distinct principles formed through the evolution of the model over decades.

This research study acknowledged these differences in the identification of what constitutes a principle and followed Merrill’s (2020) streamlined model using the five
foundational First Principles as overarching categories that integrate both the original and newly evolved elements. These generalized principles provided an overall framework for evaluating the critical instructional design components. Table 2 demonstrates how the additional principles proposed by other researchers map to Merrill’s five core principles.

For example, collaboration and collective knowledge construction strategies align with the integration principle. Differentiated instruction relates to providing examples and practice tailored to diverse learners’ needs during demonstration and application.

Adhering to the synthesized five principles allowed flexibility in operationalizing evolving design tactics while maintaining consistency in the research of Merrill’s (2020) model.

Throughout its development, Merrill’s model built upon fundamental theories while undergoing evidence-based refinement of its components. The framework maintains relevance by dynamically integrating new research on instructional strategies. This foundation in established theory and ongoing evolution based on empirical findings contributes to its widespread acceptance as a research-based instructional model (Cheung & Hew, 2015).

### Table 2

*Alignment to Course Scan Questions with Scoring Indicators*

<table>
<thead>
<tr>
<th>Item</th>
<th>Five Principles Alignment</th>
<th>Ten Principle Alignment</th>
<th>Scoring Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.01</td>
<td>Problem-centered</td>
<td>Problem-centered</td>
<td>The relevance of course objectives to real-world problems is scored holistically on a scale of 0-3, indicating the range from no relevance (0), to limited or unclear relevance (1), through moderately relevant (2), to clearly defined and directly applicable to real-world scenarios (3).</td>
</tr>
<tr>
<td>3.02</td>
<td>Problem-centered</td>
<td>Problem-centered</td>
<td>Problems are evaluated holistically for their authenticity and frequency of occurrence in real-world scenarios.</td>
</tr>
<tr>
<td>Item</td>
<td>Five Principles Alignment</td>
<td>Ten Principle Alignment</td>
<td>Scoring Indicators</td>
</tr>
<tr>
<td>------</td>
<td>--------------------------</td>
<td>------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>3.03</td>
<td>Problem-centered</td>
<td>Problem-centered</td>
<td>world settings, on a scale of 0-3, indicating the range from <em>no occurrence</em> (0) to <em>atypical or unrealistic</em> (1), through <em>moderately representative</em> (2), to <em>highly typical and reflective of real-world issues</em> (3).</td>
</tr>
<tr>
<td>3.04</td>
<td>Problem-centered</td>
<td>Problem-centered</td>
<td>The relevance of course activities to real workplace problems is scored holistically on a scale of 0-3, indicating the range from <em>no relevance</em> (0) to <em>limited relevance</em> (1), through <em>moderately related</em> (2), to <em>highly relevant and directly connected to workplace issues</em> (3).</td>
</tr>
<tr>
<td>3.05</td>
<td>Problem-centered</td>
<td>Problem-centered</td>
<td>The complexity of problems, in terms of their structure, is scored holistically on a scale of 0-3, indicating the range from <em>no problems</em> (0) to <em>well-structured with a single correct solution</em> (1), through <em>moderately complex with a few possible solutions</em> (2), to <em>ill-structured with multiple correct solutions and requiring significant analysis or synthesis</em> (3).</td>
</tr>
<tr>
<td>3.06</td>
<td>Demonstration</td>
<td>Demonstration</td>
<td>The diversity of problems is scored holistically on a scale of 0-3, indicating the range from <em>no problems</em> (0) to <em>similar or convergent problems</em> (1), through <em>a moderate variety of problems</em> (2), to <em>a wide range of highly divergent problems that cover different aspects and require varied approaches</em> (3).</td>
</tr>
<tr>
<td>3.07</td>
<td>Demonstration</td>
<td>Demonstration</td>
<td>The availability of problem solution examples is assessed on a binary scale: <em>Yes</em> (1) if there are clear and explicit examples provided within the course material, <em>No</em> (0) if such examples are absent or not readily identifiable. <em>N/A</em> if the question is not applicable.</td>
</tr>
<tr>
<td>3.08</td>
<td>Demonstration</td>
<td>Authentic Resources</td>
<td>The range of solution quality in examples is scored holistically on a scale of 0-3, indicating the range from <em>no indication</em> (0) to <em>a limited spectrum or unclear quality differences</em> (1), through <em>a moderate range showcasing some examples of varying quality</em> (2), to <em>a comprehensive spectrum with clearly defined, frequent examples spanning from excellent to poor solutions</em> (3).</td>
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<td></td>
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<td>The utilization of real-world resources is scored holistically on a scale of 0-3, indicating the range from <em>no indication</em> (0) to <em>limited or unclear use of real-world resources</em> (1), through <em>a moderate use where some resources reflect real-world settings</em> (2), to <em>a clearly defined and frequent inclusion of</em></td>
</tr>
<tr>
<td>Item</td>
<td>Five Principles Alignment</td>
<td>Ten Principle Alignment</td>
<td>Scoring Indicators</td>
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<tr>
<td>3.09</td>
<td>Problem-centered</td>
<td>Problem-centered</td>
<td>-resources that are directly reused or adapted from real-world contexts (3). The progression and scaffolding of activities are scored holistically on a scale of 0-3, indicating the range from no activities (0) to isolated or standalone activities (1), through somewhat sequential activities (2), to highly integrated activities that build upon each other in complexity and depth (3).</td>
</tr>
<tr>
<td>3.10</td>
<td>Activation</td>
<td>Activation</td>
<td>-The activation of learners' prior knowledge or experience is scored holistically on a scale of 0-3, indicating the range from no activation (0) to minimal activation (1), through moderate activation with some connections made to previous experiences (2), to extensive activation where activities are clearly designed to draw upon and integrate learners' pre-existing knowledge and experiences (3).</td>
</tr>
<tr>
<td>3.11</td>
<td>Application</td>
<td>Application</td>
<td>-The requirement for the application of knowledge or skill in activities is scored holistically on a scale of 1-3, indicating the range from no activities (0) to activities with limited or unclear application (1) through activities that provide some opportunities for application (2), to activities that clearly and frequently demand the application of new knowledge or skills in various contexts (3).</td>
</tr>
<tr>
<td>3.12</td>
<td>Integration</td>
<td>Integration</td>
<td>-The integration of new knowledge or skills into everyday work is scored holistically on a scale of 0-3, indicating the range from no integration (0) to limited or theoretical integration (1), through moderate integration where learners occasionally apply new skills to work-related tasks (2), to extensive integration with activities consistently requiring the application of new knowledge or skills in real-world work settings (3).</td>
</tr>
<tr>
<td>3.13</td>
<td>Demonstration</td>
<td>Differentiation</td>
<td>-The provision of activity options for different learning needs is scored holistically on a scale of 0-3, indicating the range from no options (0) to limited or unclear activity options (1) through a moderate variety of activities that cater to some learning needs (2), to a clearly defined and frequent selection of activities that comprehensively address a wide range of learning preferences and requirements (3).</td>
</tr>
<tr>
<td>3.14</td>
<td>Integration</td>
<td>Collective Knowledge</td>
<td>-The extent of peer learning is scored holistically on a scale of 0-3, indicating the range from no...</td>
</tr>
</tbody>
</table>
3.15 Integration Collective Knowledge
The contribution to collective knowledge is scored holistically on a scale of 0-3, indicating the range from no contribution (0) to limited contribution (1), through moderate contribution where participants are occasionally asked to add to the collective knowledge base (2), to clearly defined, frequent contributions that are integral to the course activities (3).

3.16 Integration Collective Knowledge
The requirement for learners to build upon other participants' submissions is scored holistically on a scale of 0-3, indicating the range from no requirement (0) to limited requirement for interaction with peers' work (1) through moderate engagement where learners sometimes expand upon or reference peers' submissions (2), to clearly defined, frequent expectations for learners to constructively build upon the ideas and submissions of their peers (3).

3.17 Integration Collaboration
The extent of required collaboration among course participants is scored holistically on a scale of 0-3, indicating the range from no collaboration (0) to limited collaboration (1), through moderate collaboration in which participants work together in some activities (2), to clearly defined, frequent collaboration that is integral to the course structure and learning outcomes (3).

3.18 Integration Collaboration
The level of required collaboration with individuals outside the course is scored holistically on a scale of 0-3, indicating the range from no external collaboration (0) to limited external collaboration (1), through moderate collaboration with occasional external interactions (2), to clearly defined and frequent collaboration with external parties that enhances the learning experience (3).

3.19 Integration Collaboration
The diversity within peer-interaction groups is scored holistically on a scale of 0-3, indicating the range from homogeneous groups with no diversity (0) to limited diversity (1) through groups with moderate diversity in backgrounds, opinions, and...
Table 2 (continued)

<table>
<thead>
<tr>
<th>Item</th>
<th>Five Principles Alignment</th>
<th>Ten Principle Alignment</th>
<th>Scoring Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.20</td>
<td>Integration</td>
<td>Collaboration</td>
<td>The identifiability of individual contributions within group activities is scored holistically on a scale of 0-3, indicating the range from no activities (0) to contributions that are difficult to attribute to specific individuals (1) through contributions that can be somewhat identified as individual work (2), to clearly defined and frequent mechanisms that ensure the individual contributions are distinct and recognizable (3).</td>
</tr>
<tr>
<td>3.21</td>
<td>Application</td>
<td>Feedback</td>
<td>The provision of feedback opportunities by the instructor(s) is assessed on a binary scale: Yes (1) if there are explicit opportunities for feedback outlined and accessible within the course; No (0) if feedback opportunities are absent or not explicitly stated. N/A if the question is not applicable.</td>
</tr>
<tr>
<td>3.22</td>
<td>Application</td>
<td>Feedback</td>
<td>The clarity of the feedback process is assessed on a binary scale: Yes (1) if the methods and timing of feedback are clearly outlined and understandable to participants, No (0) if the explanation of feedback provision is absent or vague. N/A if the question is not applicable.</td>
</tr>
<tr>
<td>3.23</td>
<td>Integration</td>
<td>Collaboration</td>
<td>The specificity of directions for peer-interaction groups is assessed on a binary scale: Yes (1) if there are clear, detailed instructions for group interaction provided within the course materials, No (0) if such directions are missing or insufficiently detailed for effective group interaction. N/A if the question is not applicable.</td>
</tr>
<tr>
<td>3.24</td>
<td>Integration</td>
<td>Collaboration</td>
<td>The assignment of specific roles within peer-interaction groups is assessed on a binary scale: Yes (1) if each group member is assigned a clear, defined role that contributes to the group's function and objectives, No (0) if roles are not clearly assigned or if the role distribution is ambiguous. N/A if the question is not applicable.</td>
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</table>

Support for First Principles across Instructional Contexts

One of the major strengths of Merrill’s First Principles of Instruction is that there is an extensive amount of research about the principles’ effectiveness across different
settings and subject areas (Badali et al., 2020; Cai & Moallem, 2021). This empirical evidence allows the model to be broadly applied since the principles are a synthesis of best practice strategies known to boost learning. In higher education contexts, Gardner’s (2011) meta-analysis found strong support for Merrill’s principles to be applied in technology-mediated college courses, with the most prominent effects for demonstration and application principles. Numerous additional studies have confirmed the benefits of Merrill-based instruction in university contexts across disciplines, including engineering, health professions, and agriculture (Frick et al., 2022; Merrill, 2013).

In addition to these positive findings in the higher education setting, other researchers found favorable outcomes from implementing Merrill’s model in other settings (e.g., in K-12 teacher professional development (Mendenhall, 2012), vocational mathematics (Yorganci, 2020), and high school information and communication technology courses (Lo et al., 2018)). These findings expertly demonstrated the broad applicability of the model across academic levels.

In corporate and government workplaces, Merrill’s principles have shown similar utility for designing effective training. Many studies have reported that training designed using First Principles yielded gains in learner performance and satisfaction for Fortune 500 employees, intelligence analysts, military personnel, and the government (Gara & La Porte, 2020; Graham et al., 2013; Merrill, 2022; Peterson, 2003). The model generalizes across industries and professions.

In non-Western cultural contexts, further research has provided evidence for the cross-cultural validity of Merrill’s model. For example, Cheung and Hew (2015) found that in China, business employees who received First Principles-based training showed
greater mastery of skills than those receiving traditional lecture-based instruction. The underlying cognitive mechanisms align with Merrill’s principles and apply across diverse cultures.

The ability to create instructional materials using Merrill’s principles that positively affect learning across varying contexts and learner populations demonstrates the model’s broad theoretical and empirical support. This evidence compilation helps establish its value as a research-based instructional design framework with broad utility.

**Components of Merrill’s First Principles Model**

Merrill’s First Principles of Instruction outlines five interrelated instructional design strategies, all of which are empirically grounded in prior research. The principles include:

1. **Problem-centered**: Learning is promoted when learners engage with realistic, relevant problems (Merrill, 2020).
2. **Activation**: Learners’ prior experience and knowledge are activated to establish a foundation and context for new skills (Merrill, 2020).
3. **Demonstration**: New knowledge/skills are demonstrated to learners through models and examples (Merrill, 2020).
4. **Application**: Learners apply new knowledge and skills by solving real problems (Merrill, 2020).
5. **Integration**: Learners integrate new capabilities into real-world activities (Merrill, 2020).

This framework prescribes incorporating realistic problems, leveraging prior knowledge, demonstrating concepts, scaffolding application to new contexts, integrating
skills holistically, engaging social knowledge construction, promoting collaboration, differentiating for learner needs, utilizing authentic resources, and ongoing high-quality feedback (Merrill, 2013, 2022). The principles are conceptualized as a continuous cycle that facilitates experiential learning.

**Problem-Centered**

The problem-centered principle is based on the presupposition that learning is optimized when it is centered around real-world problems that learners are likely to encounter outside the classroom (Margaryan et al., 2015; Merrill, 2020). This principle advocates for instruction that is designed around whole tasks. Presenting whole task scenarios fosters a learning environment that not simultaneously engages learners while providing them with the context needed to understand the relevance of what they are learning.

For example, Merrill (2020) demonstrated this strategy by using the problem-centered activity of selling furniture to show the series of tasks involving procedural execution. This course started with showing the salesperson how to be friendly with customers and why a first impression was important as it makes the customer more receptive to assistance. The course activated salespeople’s previous knowledge by asking them to reflect on past sales experiences and strategies. This reflection was then followed by an authentic discovery process that required open-ended questions as prying tools into customers’ needs through active listening. Additionally, the training demonstrated various potential solutions that highlighted the ability to sell products according to need (Merrill, 2020). When considering whether a course aligns with the problem-centered
principle, reviewers should find complex tasks that mirror challenges for students in their respective professions. In addition, instructors should provide opportunities for learners to present multiple perspectives and viable solutions, given that real-world problems usually have more than one solution. Instructional design reviewers should look for activities that include case studies, scenarios, or projects that can have many correct outcomes (Margaryan et al., 2015; Margaryan & Collis, 2005; Merrill, 2020).

**Activation**

The activation principle suggests that learning is improved when learners relate new information to what they already know (Cai & Moallem, 2021). When learners activate this prior knowledge, they better classify concepts, appreciate processes, and solve problems (Cai & Moallem, 2021). The theory of cognitive learning followed the idea that new knowledge is built upon previous knowledge (Gagné, 1985). New content assimilates faster if familiar ideas are brought up in class discussions. Course design can be structured in a way that relates concepts back to personal experience, which makes it more meaningful and easier to understand. Activation requires creating links between fresh data and preexisting schemas (Merrill, 2020).

When evaluating activation, reviewers should look for evidence of facilitated discussions or activities that encourage students to relate the new concepts to their existing knowledge and experiences, such as asking them to share personal examples related to the topic (Margaryan & Collis, 2005). Course materials, including written material or videos, should include references or analogies to ideas and situations learners
are likely to be familiar with, helping to form associations between the new information and existing knowledge (Margaryan, 2008).

Assessments should also require learners to access relevant prior knowledge to complete the tasks, not just repeat new information. Questions may ask students to compare or contrast new concepts to ones previously learned. As an example, Merrill (2020) described a course on sportsmanship that used STAR (stop, think, act, and replay) as a mnemonic device to activate the learner’s prior knowledge in making decisions regarding good sporting behaviors. Such memory frameworks help learners organize and recall new information by connecting it to something already known. Reviewers should check that time is provided for reflection, where learners consider how new knowledge relates to or expands on their current understanding. Reflective prompts and discussions facilitate this process.

**Demonstration**

The demonstration principle states that the learning process is enhanced when learners observe the knowledge and skills they are required to learn. This entails interactions in which students are exposed to content through “tell,” or delivery of information, and “show,” which is the depiction of the information (Merrill, 2013, 2020). Effective demonstrations often involve both the tell and the show methods, providing a rich context in which students can learn specific skills and knowledge. Merrill (2020), for example, provided an illustration of how to teach the physics of an ollie on a skateboard. In this example, “tell” would imply describing the forces and motions involved, and “show” may include videos or sequences of images depicting each stage of the ollie. This
principle applies to both general information and specific portrayal contents, which helps to balance abstract principles with concrete examples (Merrill, 2020). It also recognizes that learners have diverse learning needs, emphasizing the need for multi-modal instruction that can accommodate different learner needs (Merrill, 2020). Richer experiences are provided when course designs include multiple modalities such as videos, audio, animations, and interactive modules to get more students involved.

It is also possible to make demonstrations more effective by using tools and situations reflecting real-world ones (Merrill, 2020). In courses in which practical resources are employed by the designers, learners will understand how these materials relate to their real-life applications, promoting practical engagement with the material. This kind of learning becomes more concrete and lasting if students learn certain skills through demonstrations using instruments they would use in real life (Merrill, 2013, 2020). In the context of instructional design, reviewing a course’s alignment with Merrill’s First Principles allows reviewers to identify specific indicators of the demonstration principle’s implementation. The presence of clear, explicit demonstrations that are logically sequenced and directly tied to the learning objectives (Merrill, 2020) is one such marker. The presence of varied forms of demonstrations, such as visual aids, interactive simulations, and expert walkthroughs in the course material, indicates whether the course provides for different learning preferences (Margaryan & Collis, 2005). Another indication is that authentic resources are integrated within these demonstrations (Margaryan & Collis, 2005). A successful demonstration-based course will use real-world materials, tools, and scenarios that students are likely to face in their discipline, connecting theory with practice. Moreover, when narrative or annotations accompany
these demonstrations, they can guide learners through important aspects of the skill or concept being demonstrated, leading to the application of this principle (Mendenhall, 2012).

**Application**

The principle of application stresses the importance of learners doing tasks that enable them to perform and apply their knowledge. These tasks include interrogation, communication, or putting into practice, which is the actualization of knowledge through depiction, all important for skill acquisition (Lo et al., 2018; Merrill, 2013, 2020). Merrill’s work (2020) provided an example whereby students who had learned about pain management in a medical course were required to select the appropriate pain management plan for a patient based on his history and current symptoms in a simulated task. The principle states that learners should get intrinsic or corrective feedback and coaching during their application efforts (Cheung & Hew, 2015; Lo et al., 2018). In this context, coaching is guidance given by an instructor or system to help learners apply the knowledge they have gained. For example, when practicing medicine in a simulated environment, students can receive immediate feedback evaluating their technique so that they can make corrections (Merrill, 2020). Such instantaneous and pertinent feedback strengthens correct practices and leads the learner toward mastery of these vital skills. It is dynamic, responsive support that adjusts continually in relation to the learner’s performance by aiding when required but withdrawing these scaffolds for autonomous practice as competence increases (Merrill, 2020). At the beginning of the learning process, however, coaching might be rather direct, including steps, advising cues,
providing prompts and detailing feedback (Blazar & Kraft, 2019). As students become more skilled at something, prescriptive coaching would be applied less, enabling learners the freedom to act on their own with less supervision (Merrill, 2020).

Instructional designers reviewing course design should identify the presence of interactive tasks that require learners to apply the concepts they have learned in realistic scenarios. These tasks should challenge the learners to think critically and solve problems, moving beyond mere recall of information (Merrill, 2020). Effective application involves a spectrum of activities, ranging from simple exercises to complex real-world problem-solving (Merrill, 2020). A course that excels in applying the application principle will offer a gradual set of application tasks, progressively increasing in complexity while allowing for scaffolding. Reviewers should look for instructional designs that incorporate coaching strategies such as scaffolding so that learners are initially given a high level of support, which gradually diminishes as they become more skilled. Another indicator is the presence of feedback systems that not only correct errors but also explain why an answer is incorrect, ultimately guiding the learner toward the correct solution (Merrill, 2013, 2020).

**Integration**

The integration principle states that learners are best able to internalize new knowledge and skills when they can connect them to their everyday lives. These connections are often provided through assignments involving reflection, discussion, or defense of novel ideas in collaboration with others (Margaryan, 2008). Integration is vital as it incorporates social interaction into learning so that classmates participate actively to
give meaning and further enhance this learning experience (Merrill, 2020); for instance, Merrill gave an example of applying the integration principle by discussing a biology course developed at BYU Hawaii. This class engaged students in various activities that required them to apply what they had learned recently in solving problems. The tasks were not isolated exercises; they both cut across and within components of the course’s material, creating rich learning situations that mirror real-life interconnections among issues (Merrill, 2020).

Indicators that reviewers should look for to determine the extent to which the integration principle is present in a course include structured opportunities for learners to reflect upon what they have learned, as well as strategies that allow learners to relate the knowledge or skill to their personal or professional experiences (Yorganci, 2020). The course should include peer collaboration and discussion activities that require learners to articulate and potentially defend their understanding of the content, with participants both inside the course and community-based assignments outside of the course (Merrill, 2020).

**Empirical Support for First Principles Components**

In addition to broad support for Merrill’s model overall, research has provided specific evidence for the value of each first principle construct. Problem-centered learning shows consistent positive effects on learner motivation, comprehension, and skill (Hall, 2022). Strategies to activate prior knowledge improve integration and retention of new information (Dong et al., 2021).

Empirical studies have further supported the practice of demonstrating skills before complex application, aligning with cognitive load principles for managing
working memory (Schrire, 2006; Williams, 2005). Practice applying knowledge to realistic scenarios has been established as a means of successful transfer (Yelon, 1992; Yelon et al., 2014). Integrating new skills into daily routines has been found to enhance adoption (Buabeng-Andoh, 2012), and social knowledge construction has been shown to boost engagement and meta-cognitive skills (Garrison & Arbaugh, 2007). Akyol and Garrison (2011) concluded that collaborative application promoted higher-order thinking compared to individual work. Additionally, while learner control and differentiated instruction improved motivation and self-efficacy (Bandura et al., 1999), authentic resources provided contextual cues that aided application and transfer (Zimmerman et al., 2020). Finally, several studies indicated that systematic feedback from experts accelerated skill improvement (Bowen et al., n.d.; Margaryan & Collis, 2005). It is evident that First Principles constructs are strategic and vital for excellent instruction.

The solid empirical support for each of Merrill’s First Principles components establishes the model as an instructional design framework aligned to research-based best practices. This grounding in evidence provides a sound theoretical basis for applying the model to evaluate instructional quality.

**Merrill’s First Principles for Evaluating Online Learning Designs**

Merrill’s instructional design principles translate effectively from guiding the creation of instruction to serving as criteria for evaluating instructional materials and products (Merrill, 2007). The components offer a research-based checklist of critical strategies that quality instruction should embody.

For asynchronous online learning, when dynamic instructor-learner interaction is limited, quality design is even more critical for student success. Without a teacher present
to adapt in the moment, the course itself must engage diverse learners. Merrill’s principles align closely with best practices for online course design that have been identified in studies, including clear objectives, authentic assessments, and facilitated discussions (Hixon et al., 2016).

Quantitative studies examining online course quality provide support for using Merrill’s model as an evaluation framework (Margaryan et al., 2015). Quantitative content analysis of 76 Massive Open Online Courses (MOOCs) using Merrill’s principles as a coding guide revealed significant gaps in compliance with established design standards (Margaryan et al., 2015). Quantitatively measuring alignment with Merrill’s principles exposed specific deficits in online course quality.

Empirical research also demonstrated that Merrill’s model was robust across different online learning contexts. The principles effectively evaluated designs from small private institutions to informal MOOCs (Margaryan, 2008; Merrill, 2022). While qualitative and quantitative assessments based on Merrill’s standards can strengthen evaluations of quality in online course designs, a gap exists in research concerning online courses designed at public universities.

**Defining and Evaluating Quality in Online Course Design**

A major challenge in evaluating online course quality is the lack of consensus on what constitutes *quality* in course design (Gregory et al., 2020; Zimmerman et al., 2020). Stakeholders such as instructional designers, administrators, instructors, and students may have differing perspectives on which elements are most important for a high-quality online learning experience (Allen & Seaman, 2013; Bolliger et al., 2014). Despite disagreement about standards and priorities, ensuring quality is critical for student
success and institutional outcomes in online education. For example, research by Hawkins et al. (2013) indicated that students enrolled in online courses with perceived high levels of instructor interaction had higher course completion rates than those with lower levels of interaction. To promote quality assurance, many institutions utilize practices such as rigorous peer review of course materials, standardized quality rubrics, and required faculty training programs in online best practices (Legon, 2015). Though consensus on a single definition of online course quality is unlikely, focusing on evidence-based practices that directly improve student learning and persistence should be a priority (Bali, 2014; Frick et al., 2010).

Several frameworks have attempted to define the ambiguous dimensions of quality. A systematic review by Kauffman (2015) proposed constructs of quality based on the frequency of appearance in models: institutional support, course development, teaching and learning, course structure, student support, faculty support, evaluation, and assessment, as well as the use of technology. The Online Learning Consortium (OLC) outlined five pillars of quality focused on learning effectiveness, scale, access, faculty satisfaction, and student satisfaction (Gómez-Rey et al., 2016; Mathes & Shelton, 2023). E-xcellence, a method to assess online course quality developed in Europe, defined six areas of importance: strategic management, curriculum design, course design, course delivery, staff support, and student support (Rosewell et al., 2017). Quality Matters is another framework that provides standards and a peer review process for ensuring quality in online and blended courses (Gregory et al., 2020). Quality Matters defined eight components of its quality framework: course overview and introduction, learning objectives (competencies), assessment and measurement, instructional materials, learning
activities and learner interaction, course technology, learner support, and accessibility, as well as usability (Quality Matters, 2023). These frameworks provide a foundation, but reaching a consensus on measuring and assessing quality remains difficult due to differing priorities by role and institution type. Further research is needed to synthesize empirical findings on the dimensions of online course design quality that demonstrate the most substantial relationships to student outcomes.

Numerous studies have analyzed rubrics for evaluating online course designs in higher education institutions, representing efforts to establish the criteria and benchmark quality across contexts. Baldwin et al. (2018) investigated six publicly available rubrics and found that there was consistency concerning what constituted quality in terms of a course summary, goals, evaluation procedures, student involvement, and accessibility based on alignment with instructional design standards. A study of the Quality Matters rubric showed high interrater reliability and agreement on such principles as setting objectives, promoting engagement, and communicating expectations (Legon, 2015).

Merrill’s First Principles of Instruction is a common instructional design framework (Cai & Moallem, 2021; Merrill, 2013). The central strategies advocated by these principles include problem-based learning approaches in which students are encouraged to find solutions to real-world issues, activate background information, demonstrate new skills, apply knowledge to real-life scenarios, and integrate skills into learners’ experiences (Gardner, 2010). The literature has shown strong empirical evidence for Merrill’s model regarding its ability to enable learning across different subjects (Frick et al., 2022; Gardner, 2011; Gardner et al., 2020).
One benefit of Merrill’s principles for evaluating course design quality is the high level of specificity. Collis and Margaryan (2005; 2015) expanded a rubric breaking down each of Merrill’s principles into quantifiable indicators with criteria for met/not met. This rubric demonstrated high interrater reliability between evaluators examining the same courses.

**Gaps in the Literature and Application at Public Universities**

Despite growth in online enrollment, there remains limited research on design quality at public four-year universities, which differ from vocational colleges and small liberal arts colleges in mission, student profile, and program mix (Clark, 2001; Garrett & Hecock, 1984). Some studies focused on other frameworks for evaluating online course design quality, such as Quality Matters, while others emphasized student or faculty perspectives (Gregory et al., 2020). Most studies using Merrill’s principles as an evaluation framework investigated private institutions, MOOCs, or multi-institution samples.

A limitation of these studies is the focus on large multi-institution, secondary school, or MOOC samples, providing little insight into quality at public, four-year universities. Two dissertations have applied Merrill’s principles quantitatively within similar public education contexts. Chukwuemeka et al. (2015) used a Merrill-based rubric to evaluate 27 open online courses in Europe; they found some compliance with differentiation and authentic recourses but almost no compliance with application and integration. A similar, two-stage study of four secondary schools focused on flipped classrooms; this study found that courses with a higher extent of First Principles lead to higher levels of student achievement (Lo et al., 2018). Milakovich and Wise (2019) also
found that Merrill’s principles were not implemented consistently in assessing online courses at a technical college. Both studies demonstrate the value of localized data, but they are limited to small sample sizes at specific institution types.

Two other investigations used Merrill’s model to study online course quality at public universities, but these studies also had limitations. First, Klein and Mendenhall (2018) performed a qualitative investigation analyzing the rapid production of professional development courses for online delivery using Merrill’s First Principles of Instruction. Findings revealed that many personal and environmental factors influenced the execution of the First Principles of Instruction (Klein & Mendenhall, 2018). Time constraints were also found to have a major impact on successfully applying the principles. Furthermore, designer experience played a role in applying the principles as novice designers focused more on the challenges of converting courses to the online environment rather than utilizing the First Principles. In the study, participants felt that initial training was insufficient because it did not follow the First Principles or provide adequate practice for novice designers before integrating them into the project, suggesting that to successfully apply the First Principles of Instruction, designers need to be experienced or have assistance from experienced instructional designers, with time enough to dedicate to application. Another study investigated student perceptions in nine online nursing courses; this study investigated participants’ opinions on how well their courses aligned with Merrill’s principles rather than directly evaluating course design (Anderson et al., 2015). This study found that Merrill's First Principles of Instruction were reliable factors that impact students' perceptions of online course quality.
The lack of robust, quantitative application of Merrill’s principles to evaluate design quality within public university contexts represents a significant gap. Large public institutions face unique challenges in online learning related to student diversity, faculty technology proficiency, decentralized governance, and strained resources (Bolliger et al., 2019; Eckel & Kezar, 2003; Shachar & Neumann, 2010). Directly measuring adherence to research-based design standards can help target initiatives to address these barriers. The proposed study will apply quantitative content analysis using Merrill’s widely researched instructional design criteria to help fill this gap.

Quantitative methods allow measurement of compliance with Merrill’s principles. In 2005, Collis and Margaryan expanded the original five-criteria instrument developed by Merrill (Margaryan & Collis, 2005; Merrill, 2002b). The Merrill+ design and evaluation criteria based on Merrill’s five principles were developed to assess asynchronous online courses quantitatively. Later, it expanded into Course Scan. The new instrument included 37 questions examining the First Principles and showed high interrater reliability (Margaryan et al., 2015).

Summary

This literature review has synthesized research on assessing and improving quality in online course design, focusing on applying instructional design principles and models as evaluation lenses. Despite rapid growth in online learning, there remains limited consensus on definitions, standards, and methods for evaluating online course design quality. Researchers have proposed multidimensional frameworks outlining aspects of quality, with dimensions related to instructional design emerging frequently (Kauffman, 2015; Mathes & Shelton, 2023). However, many universities continue to use
locally developed evaluation methods that lack reliability and validity. To move beyond these locally developed assessments, empirical studies leverage instructional design models that encapsulate research-based practices to evaluate course elements against objective criteria. A review of quality assurance rubrics and publicly available standards emphasized the importance of aligning course objectives, assessments, interactions, and activities to core instructional design principles (Baldwin & Ching, 2021; Legon, 2015). This demonstrates the value of grounding quality evaluations in established learning theory and evidence-based practice.

Of available instructional design models, Merrill’s First Principles of Instruction (2002b) is among the most extensively researched and widely applied models across contexts. The First Principles demonstrated instructional strategies, including problem-centered learning, activation of prior knowledge, demonstration of skills, authentic practice, and integrated application. Each of these principles is independently supported through empirical studies as an effective component of instructional design (Cai & Moallem, 2021; Lo et al., 2018; Merrill, 2022).

However, a gap found in the literature is a lack of comprehensive, quantitative application of Merrill’s model specifically to assess the quality of asynchronous online courses at public four-year universities. Most existing research utilizes Merrill’s principles in MOOC, vocational, liberal arts, or private university contexts. The few studies situated at public institutions rely on small qualitative samples or indirect measures rather than robust quantitative content analysis. Public universities contend with unique challenges related to student diversity, faculty technology skill gaps, decentralized governance, and resource constraints that impact online learning (Bolliger
et al., 2019; Shachar & Neumann, 2010). This study addressed this need for quantified evaluation of design quality using Merrill’s validated model in this understudied context.
CHAPTER THREE: METHODOLOGY

This study investigated the quality of online course design using Merrill’s (2020) First Principles of Instruction. A quantitative content analysis methodology examined a majority sample population of thirty STEM CAS courses at a public southeastern university. The research literature demonstrated that a quantitative content analysis methodology was a valid and appropriate method to effectively measure content characteristics within asynchronous online courses (De Wever et al., 2006; Huxley, 2020; Meyer, 2019; Rourke & Anderson, 2004). This chapter details the design, framework, coding instrument procedures, data collection methods, setting, analysis, and investigation methodology used to answer the following research questions:

Research Question 1. To what extent, if at all, does the design of the College of Arts and Sciences’ asynchronous online STEM courses reflect the First Principles of Instruction?

Research Question 1. To what extent, if at all, are the College of Arts and Sciences’ asynchronous online STEM courses problem-centered?

Research Question 2. To what extent, if at all, do the College of Arts and Sciences’ asynchronous online STEM courses demonstrate activation of existing experience?

Research Question 3. To what extent, if at all, do the College of Arts and Sciences’ asynchronous online STEM courses reflect the principle of demonstration?

Research Question 4. To what extent, if at all, do the College of Arts and Sciences’ asynchronous online STEM courses enable learners to apply their new knowledge or skill to solve problems?
Research Question 5. To what extent, if at all, do the College of Arts and Sciences’ asynchronous online STEM courses encourage learners to integrate new knowledge or skill?

Research Question 6. To what extent, if at all, does the design of the College of Arts and Sciences’ asynchronous online STEM courses reflect the First Principles of Instruction?

The Investigation Plan

I conducted a quantitative content analysis to explore the degree to which Merrill’s First Principles of Instruction are present in the design of asynchronous online courses at a public state university located in the southeast United States of America. Data was gathered on a sample population of thirty online courses in five categories to describe the university’s STEM courses in the College of Arts and Sciences’ current state of online course design quality. Quality in instructional design can be measured in several ways (Meyer, 2019). For this study, the literature was reviewed, and the longstanding and well-researched theoretical foundation of Merrill’s First Principles of Instruction (Merrill, 2022) was selected as a framework to define quality in STEM online courses. A sample of thirty STEM courses offered by the College of Arts and Sciences in an asynchronous, online modality in a single academic year, 2022-2023, across three semesters; fall, spring, and summer, was reviewed for the study. Three coders with multi-year experience with online course design quality assessment evaluated the content for the courses using Merrill’s First Principles of Instruction. Descriptive statistical analysis were conducted using IBM SPSS™ version 29.
Quantitative content analysis was chosen as the design to systematically study and quantify the characteristics of the course content. This research technique originally came from analyzing propaganda in World War II as researchers tried to objectively measure and understand what was in media messages (Huxley, 2020). The fundamental approach to quantitative content analysis is to take media such as texts, videos, and audio to categorize and count content features using a structured coding system (Anderson et al., 2001; Meyer, 2019). This method allows researchers to statistically describe communication patterns. The process is adaptable for a variety of media analysis, from books to social media, and is a proven tool for evaluating online course designs (Meyer, 2019; Tan et al., 2011).

In this study, quantitative analysis cataloged the extent to which instructional design principles were incorporated into STEM courses based on Merrill's First Principles of Instruction framework (Merrill, 2013, 2020), an effective instructional design framework detailed in Chapter 2. The course content was reviewed and rated on the inclusion of Merrill's research-backed set of design standards for effective learning. This coding process generated measurable data that quantified the extent of quality design elements.

These initial benchmarks provided a starting point to track content characteristics. Follow-up studies under varied conditions can now use hypothesis testing to systematically assess differences going forward. The core quantitative analysis method here allowed a structured evaluation of how the current course design stands regarding established instructional guidelines. Overall, quantitative content analysis offered a flexible way to understand textual information. Its systematic approach was appropriate
for descriptive statistics about the online course data in this study (Rourke & Anderson, 2004). More specifically, a descriptive content analysis design was selected to observe the substantive characteristics of the university’s online courses as they were designed without influence or interference. The study established boundaries to accomplish this aim by including only STEM courses from the College of Arts and Sciences at the target university over one academic year.

Trained coders reviewed each course using the validated Course Scan instrument based on Merrill’s First Principles of Instruction. Multiple coders rated each course, and inter-rater reliability was established. The coders used the instrument to analyze the instructional design quality of meaning units within each course. Descriptive statistics, including means, medians, modes, and standard deviations, were calculated to quantify overall design quality and to identify potential areas for improvement. The results provided insight into the current state of online course design aligned with research-based principles at this university.

**Delimitations and Weaknesses**

While several steps have been taken to reduce bias and aid in consistent and repeatable content analysis, the chosen approach does include boundaries and limitations. Online courses included in this study were from a single academic year, 2022-2023. All courses from which the selection was taken are also offered at a mid-size state university and may not be representative of other higher academic structures. The university’s regional mission and the available resources for instructional design and training of online course developers may also differ across the higher education landscape. Finally, the COVID-19 pandemic required that several courses be transitioned from traditional in-
person modalities to online in a short time and without the intentional use of best practices. While many of these courses were labeled as remote rather than online and would not be part of the selection, some could have been tagged as online and reflected in the content analysis. Finally, the selection was chosen from all STEM online courses in an academic year and was not specific to a single department, subject matter, or level of education.

**Selection**

This research selected asynchronous online STEM courses designed at a public university in the southeast United States of America. The university defines an online course using “Web” as the instructional method type. A course designated as “Web” at this university is a fully online course, indicating that the course is delivered via a learning management system and has no required in-person meetings.

Synchronous courses, courses with required virtual sessions and remote courses, and courses with a special designation that were quickly moved from traditional, in-person to remote delivery due to the COVID-19 pandemic, were also excluded.

The university offered a total of 785 asynchronous online courses during the 2022-2023 academic year. Given the time and labor-intensive review work, it was determined that a census of the 785 total online offerings found was not plausible in the timeframe of this study. As such, the total analysis was limited to the STEM disciplines in the College of Arts and Sciences, the university’s largest and most varied college. The College of Arts and Sciences offers a diverse range of STEM disciplines, including biological sciences, chemistry, computer science, engineering, epidemiology, geoscience, physics, and technology, as well as both undergraduate and graduate-level courses. The
total number of CAS STEM online courses offered in an asynchronous format during the 2022-2023 academic year was 53.

**Setting**

The setting for this research is a mid-sized, public, fully accredited state university. The university is located in the upper southeastern region of the United States of America and has been offering online courses for more than 20 years. The majority of attending students are regional. The media type for the content analysis was the instructional design, structure, and content of an online course offered in the academic year 2022-2023.

The university offers online courses via the learning management system (LMS) Brightspace™, which hosts the basic structure for all offered online courses. Brightspace™ offers instructional designers and faculty the ability to add learning modules, assignments, assessments, and discussions, as well as to manage grades and students’ progress. Multimedia elements such as video, audio, images, slides, and documents can be integrated. Collaboration tools include discussion forums, chat boards, and virtual web conferences. Instructional designers and faculty can also utilize third-party elements integrated into or linked from the LMS. The unit of analysis was a single online course hosted on Brightspace™, which can be broken down into learning modules, web pages, and digital elements.

**Instrumentation**

The extent to which the First Principles of Instruction were present in the university’s online courses was measured with Course Scan, a questionnaire instrument designed to gauge the instructional design quality of a course regarding the five
principles that make up Merrill’s First Principles of Instruction. Developed by Margaryan and Collis (2005), this version of Course Scan was selected for this present research due to its alignment with online course design. The complete Course Scan instrument is included in Appendix A.

The First Principles of Instruction is an appropriate lens to quantify online course design quality; according to Merrill’s (2013) meta-review, the First Principles reflected the foundation for all modern instructional design theories and models. Gardner (2011) supported this supposition with a systematic study of 22 contemporary theories on instructional design. Margaryan (2008, 2005) expanded the First Principles and validated the Course Scan evaluative framework on over one hundred distance courses in higher education.

Course Scan includes two primary quality measurement sections: a section detailing objectives and organization (6 items) and a section focusing on First Principles (24 items). An initial section allows for collecting course information such as course titles, dates, and other categorization information (7 items). The range of scores is 0 to 72 points, divided into three sections. The first section includes course details made up of items without a numeric score. The second section is objectives and organization, which include questions such as: does the course specify the learning population and accounts for ten total points – however, these questions are not linked to specific Principles as stated by Merrill. The third section includes questions based on Merrill’s First Principles and accounts for 62 total points. The course information is collected with fill-in-the-blank questions, while objectives, organization, and first principal questions are a mixture of binary (yes/no) questions and Likert-type ranges to quantify the extent of the principles.
Table 2 aligns each of the First Principles to the specific questions on the instrument and scoring indicators used by reviewers. The questionnaire was administered to three expert reviewers using Microsoft Forms, and data was collected in Microsoft Excel for analysis in SPSS.

The Course Scan instrument does not include any set ranges to interpret data once collected. For example, authors Margaryan et al. (2015) indicated that the MOOC courses they analyzed scored low on average out of the 72 possible points. However, they did not explain what low meant to them or what threshold scores would have needed to be considered moderate or high. This study breaks down the resulting scores into five ranges for clarity and consistency in future comparative studies.

Table 3

*Levels of Principle Integration*

<table>
<thead>
<tr>
<th>Percentage Range</th>
<th>Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% - 20%</td>
<td>Minimal integration. The principle is barely acknowledged or reflected in the course.</td>
</tr>
<tr>
<td>21% - 40%</td>
<td>Low integration. There are some elements of the principle present, but they are limited.</td>
</tr>
<tr>
<td>41% - 60%</td>
<td>Moderate integration. The principle is evident in parts of the course, though not consistently across all components.</td>
</tr>
<tr>
<td>61% - 80%</td>
<td>High integration. The principle is a clear, recurrent theme in the course, significantly shaping content, activities, and assessments.</td>
</tr>
<tr>
<td>81% - 100%</td>
<td>Full integration. The principle is central to the course, thoroughly infused in all aspects, and clearly demonstrated.</td>
</tr>
</tbody>
</table>

**Coders**

Human coders were selected over automated computer scanning methods due to the complexity and variety of ways course designers can structure or share information in
a course. Human coders with experience in instructional design are better able to make inferences and evaluate the effectiveness of various design elements (Conway, 2006). The selection of expert instructional designers as coders for this study was grounded in the existing literature on characteristics and qualifications that distinguish expert performance in the field. Bratton (1983) defines an expert instructional design specialist as someone who can successfully carry out the instructional development process in collaboration with a subject matter expert, quickly comprehend and analyze problems, offer solutions based on professional judgment, design evaluation methods, and suggest alternative instructional design solutions as needed. Importantly, Bratton (1983) emphasizes that expert instructional designers must possess both strong technical skills and interpersonal competencies.

Building on this foundation, Ertmer et al. (2008) characterize expert instructional designers as those with several years of experience in diverse settings, an ability to efficiently diagnose problems and consider instructional solutions by drawing on well-organized domain knowledge and practical experience, and a guiding cognitive framework or model of the design process. The authors note that while expert designers may vary in their specific conceptualizations, they tend to reach similar conclusions about addressing ill-structured design challenges. Ertmer et al.’s (2008) study provides a more precise operational definition of expertise based on experience and observable problem-solving strategies.

Maistre (1998) elaborates on the cognitive dimensions of expert instructional design performance, highlighting a rich and well-organized knowledge base, deep problem representation, extensive front-end analysis, efficient search strategies, and
strong self-monitoring and metacognitive skills as key characteristics distinguishing experts from novices. Maistre (1998) also references previous literature’s assertions that years of deliberate practice are typically required to develop expertise while cautioning against relying solely on a particular number or range of years of experience as a definitive measure.

Incorporating these perspectives and noting disagreements, this study sought expert instructional designers, such as those with several years of professional experience in varied contexts, who demonstrated proficiency in applying evidence-based design principles and practices. This definition aligns with the criteria identified in the research literature, emphasizing a combination of technical knowledge, practical experience, problem-solving skills, and interpersonal competencies as the hallmarks of expertise in instructional design (Bratton, 1983; Ertmer et al., 2008; Maistre, 1998). Instructional designers at the university were contacted via email requesting interest and availability. Of respondents who qualified using these criteria, three coders were available for the study. An a priori coding using the established and verified categories of Course Scan aligned the instrument with the theoretical framework. Two of the three available coders reviewed all thirty sample courses, with each coder reviewing a total of 20 courses. All three coders were experienced in the theories of Merrill’s First Principles of Instruction, online instruction, and the Course Scan instrument. Six pilot courses (20%) of the thirty sample courses were utilized. These pilot study courses were used for each researcher to review and discuss until inter-rater agreement reached a kappa of .9 or greater (Coder set 1 kappa = .92, Coder set 2 kappa = .92, Coder set 3 kappa = .95). After the pilot study, each course was reviewed by at least two coders. With each of the thirty courses
reviewed by two coders, three coder pairs were analyzed for agreement using Cohen’s kappa statistical measure to ensure inter-rater reliability. Coder set 1 (Coder 1 and Coder 2, kappa = .71) and Coder set 2 (Coder 2 and Coder 3, kappa = .78) demonstrated substantial agreement with kappa statistical measures between .61-.80 (Cohen, 1960). Coder set 3 (Coder 1 and Coder 3, kappa = .81) demonstrated higher agreement with a kappa statistical measure greater than .81 indicating almost perfect agreement (Cohen, 1960).

**Procedures**

Data was collected in 2024 based on the 2022-2023 online courses offered. The academic year for the university includes three semesters: Fall 2022, Spring 2023, and Summer 2023. Data files were collected from the university’s enterprise resource planning (ERP) system called Banner. Data files were pulled individually by semester and included information about all courses for that semester, including in-person and inactive courses. Three files were created from Banner using the Argos reporting system, resulting in three CSV formatted files. Data only included the courses built during those semesters; no content or instructional design data was included. All three CSV formatted files were combined into a single data file using Microsoft Excel™. Data was first filtered by the status indicator, removing inactive and keeping active courses. This indicated that the course was offered and not canceled. Data was then filtered by the instructional method of “Web,” which the university used to indicate an online course. Online courses identified as “Web” may still have included synchronous, remote courses, and asynchronous courses as designated by a section number, a three-digit identifier that accompanies the subject code, and the course number for each course. Asynchronous
online courses at the university use a section number between 900 and 989. Courses were further filtered to these sections, indicating that the active online offering used an asynchronous modality. Depending on the number of enrollments in a program, courses may be offered more than once a semester at different times, using different modalities or different instructors. These courses have the same subject code and course number but different section numbers. Typically, these courses are combined within the university’s learning management system so multiple sections can use the same content and instructional design. Other times, content is copied from one section to another of the same course offering. Using Microsoft Excel™, multiple asynchronous sections were removed, leaving one unique offering per online course. With data combined and filtered, the result was a total of 785 courses actively offered in an asynchronous online format during the 2022-2023 academic year.

Using Microsoft Excel™, the 785 total asynchronous online courses were filtered by college, leaving 169 total CAS asynchronous online courses. These 169 online courses were then filtered by subject to only include STEM disciplines: biology, biostatistics, chemistry, computer science, engineering, epidemiology, geoscience, physics, surveying and mapping, and technology, leaving 53 online courses. A random majority sample of thirty courses was selected to be reviewed from the total population of 53 STEM field asynchronous online courses offered by the College of Arts and Sciences during 2022-2023. This majority sample included spring, fall, and summer semester courses and graduate and undergraduate-level courses.

The thirty randomly selected courses’ instructional design content and structure were copied into separate development shells within the Brightspace learning
environment. This method isolated the reviewers from accessing student or instructor data and captured the course structure at a single point in time. Reviewers had view-only access to the review course shells for analytical purposes. No one beyond the learning management system administrators could edit the shell. The review shells were deleted from the system after the study concluded. The study was examined by two university institutional review boards (IRB); however, the review or approval was deemed unnecessary as the research activity did not meet the Office of Human Subjects Research Protection’s definition of research with human subjects.

To ensure a systematic and replicable analysis process, the instructional designers followed a structured procedure when reviewing each course. First, the coders accessed the copied course shell in the institution's learning management system. This shell contained all course elements but no student data or interactions. The analysis involved the coders reviewing course elements to answer each question in the Course Scan instrument. The number of course elements that do or do not integrate with a principle helped rationalize the coder’s score. However, not all course elements have the practical potential for a First Principle to be included. For example, an instructor may have a faculty introduction included in the course, which would not count for or against the score of a particular Course Scan item. The coders limited their analysis to course descriptions and objectives, materials and resources, learning activity information, and discussion prompts. Materials and resources were varied and may include written content and multimedia content such as audio, video, and interactive software. Some material was housed inside the learning management system, while others were linked to web-based resources. Learning activity information was varied and included instructions for
any graded or ungraded activity to be completed by a student or a group of students, including examples and rubrics, if any, and feedback expectations and opportunities. Discussion prompts were found in the syllabus, content area, or discussion tool and included instructions for student interaction, examples, rubrics, and assessment and feedback opportunities and expectations, if any.

The reviewers began by thoroughly examining the course syllabus, paying close attention to the learning objectives, course requirements, and schedule of topics. They then proceeded to each learning module in sequence, comprehensively reviewing each of the course elements listed above. Coders looked for clear evidence of each principle as guided by the Course Scan instrument and by examples and markers described by Merrill (Table 2), taking detailed notes on how and to what extent the principle was implemented (Margaryan & Collis, 2005; Merrill, 2020).

For each principle, the reviewers considered factors to determine the appropriate score. They calculated the percentage of appropriate course elements that incorporated the principle. For instance, for items asking about real-world problems, if a course contained ten learning activities and seven of them involved learners solving real-world problems, that item would be rated as 70% “to a large extent” problem-centered. Similarly, if 2 out of 12 instructional activities included worked examples demonstrating the skills to be learned, that item would score 17% “to some extent.” The specific thresholds for each score level were provided in the Course Scan instrument (Margaryan et al., 2015) as follows:

- “None”: Not evident
• “To some extent”: There are serious omissions or problems; the principle is reflected in fewer than 50% of items (e.g., activities or objectives) being evaluated.

• “To a large extent”: Generally OK, but there are some omissions or problems; the principle is reflected in between 51% and 80% of items being evaluated.

• “To very large extent”: Excellent; the principle is reflected in between 81% and 100% of items being evaluated.

To determine if a specific activity, assignment, or instructional component implemented a principle, coders evaluated the depth and clarity, if any, with which the principle was. For example, a course activity that included an authentic, complex problem would be rated higher than one with only superficial problem-solving tasks tacked onto otherwise straightforward content (Margaryan, 2008; Merrill, 2020). The Course Scan instrument does not provide specific criteria, thresholds, or examples for determining how or if an individual item should score on Likert-style range items. Also, similar studies such as Margaryan et al. (2015) review of MOOCS do not provide specific guidance on how individual items were scored, leaving the rating up to the judgment of the coders based on their instructional design experience, highlighting the need for experienced coders. After closely examining all course components, the coders reflected and assigned the corresponding score for each item using the Course Scan rubric. While the process was consistently applied across courses, the specific time required varied based on the complexity and amount of material in each course.
The reviewers did not necessarily have in-depth subject matter expertise in the specialized STEM fields of the courses they evaluated. To mitigate this limitation, the reviewers focused on the pedagogical implementation of the First Principles rather than the accuracy or relevance of the disciplinary content itself. For example, when assessing problem-centeredness, the reviewers looked for the structural alignment of course objectives, activities, and assessments with the problem-solving process rather than judging the quality of the problems themselves (Merrill, 2002b). Similarly, for activation of prior knowledge, the focus was on identifying techniques used to help learners connect new material to existing knowledge, not the accuracy of the connections. However, future studies could be strengthened by including subject-matter expert’s opinions alongside instructional designers.

**Example Review**

To demonstrate how reviewers evaluated courses using the Course Scan instrument aligned to Merrill’s First Principles of Instruction, the following section details an example review of BIOL-1010, Introduction to Biology, a mock undergraduate, asynchronous online course. This case and course are hypothetical and not a genuine sample of one of the thirty reviewed courses, but it is representative of an actual course. To begin, Coder 1 accessed a view-only shell of BIOL-1010 containing the learning modules, assignments, assessments, and other course materials needed to assess the presence of instructional design principles.

Coder 1 examined whether BIOL-1010 specified the learner population that will engage in the course (Item 2.1). Item 2.1 is a binary *yes* or *no* option. Coder 1 investigated several relevant elements of the course, including course descriptions and
objectives, materials and resources, learning activity information, and discussion prompts, but the course failed to explicitly specify the learner population. Coder 1 marked Item 2.1 as no. Coder 1 explored Item 3.10: To what extent do the activities attempt to activate learners’ relevant prior knowledge or experience? Restarting at the beginning of the course, Coder 1 sought evidence that activities activated learners’ relevant prior knowledge by examining relevant course activities, such as course descriptions and objectives, materials and resources, learning activity information, rubrics and examples, and discussion prompts. The following represents example notes taken by Coder 1 during the investigation of Item 2.1 and Item 3.10:

- Coder 1: Review018
  - Item 2.1. Does the course specify the learner population that will engage in the course?
    - The syllabus did not address the learner population.
    - The remaining course descriptions and objectives, materials and resources, learning activity information, and discussion prompts failed to explicitly specify the learner population.
    - Item 2.1 marked as no.
  - Item 3.10: To what extent do the activities attempt to activate learners’ relevant prior knowledge or experience?
    - Course introduction module: The instructor built on the previous course, suggesting students refresh their previous knowledge and
explicitly stating that course information would build on previous knowledge.

- Course Activity 1: Notes: Multiple choice test, one correct answer each, content explicitly covered in the module. No explicit activation of prior knowledge.

- Course Activity 2: Discussion prompt: The prompt asked students to relate the concept to something from their past experience, activating prior knowledge. Prompt primed learners for a presentation later in the course.

- Course Activity 3: Notes: Multiple choice test, one correct answer each, content explicitly covered in the module. No activation of prior knowledge.

- Course Activity 4: Notes: Multiple choice test, one correct answer each, content explicitly covered in the module. No activation of prior knowledge.

- Course Activity 5: Discussion prompt: The prompt asked learners about current content without activating or linking to prior knowledge.

- Course Activity 6: Notes: Multiple choice test, one correct answer each, content explicitly covered in the module. No activation of prior knowledge.

- Course Activity 7: Presentation. Learners are asked to present a topic in video format. One of the rubric criteria explicitly asked
learners to show how they had built on an experience from their past, activating prior knowledge from the previous courses.

- Out of 8 practical opportunities for activation, three demonstrated activation, less than 50%. Item 3.10 is marked as *To some extent*.

Coder 2 repeated the process, and an analysis of their scores revealed that there was some disagreement between Coder 1 and Coder 2 concerning how the activation principle (item 3.10) was rated. To address this discrepancy, an average of item scores was used to determine a single score for this course.

**Analysis**

At least two of the three coders reviewed each course in the sample. For each of the sampled courses, a total of 72 points was possible, with a minimum of 0 points. A score of 0 indicated that the course showed no evidence of Merrill’s First Principles of Instruction or organizational measures, while a score of 72 implied that the course design exemplified the First Principles of Instruction and organizational criteria at an exceptionally high level (Table 3). The range of scores for all sample courses, as well as the mean, median, mode, and standard deviation, were calculated. Descriptive statistics were also calculated for each individual principle construct. Each item on the instrument was either a Likert-type scale or a binary scale. Likert-type items were rated with the following ratings: 3 = *to a very large extent*, 2 = *to a large extent*, 1 = *to some extent*, or 0 = *no evidence of the principle was found*. Binary-type items were rated with the following ratings: 1 = *Yes*, or 0 = *No*. Table 4 succinctly presents this information.
Table 4

Research Question Alignment to Analysis and Potential Score

<table>
<thead>
<tr>
<th>Research Question Reflection</th>
<th>Analysis Descriptive Statistics (DS)</th>
<th>Potential Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Problem-Centered</td>
<td>DS on scores for questions 3.1-3.5, 3.9</td>
<td>18</td>
</tr>
<tr>
<td>2 Activation</td>
<td>DS on scores for question 3.10</td>
<td>3</td>
</tr>
<tr>
<td>3 Demonstration</td>
<td>DS on scores for questions 3.6-3.8 and 3.13</td>
<td>10</td>
</tr>
<tr>
<td>4 Application</td>
<td>DS on scores for questions 3.11, 3.21-3.22</td>
<td>5</td>
</tr>
<tr>
<td>5 Integration</td>
<td>DS on scores for questions 3.12, 3.14-3.20, 3.23-3.24</td>
<td>26</td>
</tr>
<tr>
<td>6 First Principles of Instruction</td>
<td>DS on total scores&lt;sup&gt;a&lt;/sup&gt;</td>
<td>72</td>
</tr>
</tbody>
</table>

<sup>a</sup>The total score of 72 points included the 10 points from section 2 of the Course Scan instrument. While section 2 addresses objectives and organization, it does not directly assess the course’s alignment with specific First Principles of Instruction.
CHAPTER FOUR: RESULTS

Chapter four presents the findings from the content analysis evaluating the extent to which the design of asynchronous online STEM courses offered by the College of Arts and Sciences reflected Merrill’s First Principles of Instruction. This study aimed to assess the extent, if any, to which asynchronous online STEM courses designed at a university incorporate Merrill’s First Principles of Instruction. The research questions were:

Research Question 1. To what extent, if at all, are the College of Arts and Sciences’ asynchronous online STEM courses problem-centered?

Research Question 2. To what extent, if at all, do the College of Arts and Sciences’ asynchronous online STEM courses demonstrate activation of existing experience?

Research Question 3. To what extent, if at all, do the College of Arts and Sciences’ asynchronous online STEM courses reflect the principle of demonstration?

Research Question 4. To what extent, if at all, do the College of Arts and Sciences’ asynchronous online STEM courses enable learners to apply their new knowledge or skill to solve problems?

Research Question 5. To what extent, if at all, do the College of Arts and Sciences’ asynchronous online STEM courses encourage learners to integrate new knowledge or skill?

Research Question 6. To what extent, if at all, does the design of the College of Arts and Sciences’ asynchronous online STEM courses reflect the First Principles of Instruction?
It utilized a quantitative content analysis of thirty STEM courses offered by the university's College of Arts and Sciences during the 2022-2023 academic year. The study used the framework of Merrills' First Principles of Instruction to identify elements of course design across disciplines, levels, and semester types. Mean, median, mode, standard deviation, and range were calculated and reported for each principle. The interpretation and implications of the results will be discussed in Chapter 5.

**Results**

**Research Question 1: Problem-Centered Principle**

Research Question 1 measured the degree to which courses integrated problem-centered instruction, which Merrill defines as “when learners acquire knowledge and skill via a problem-solving strategy in the context of real-world problems or tasks” (Merrill, 2020, p. 4). The coders rated this principle using six items, and scores for each course could range from 0-18 (Table 2). Descriptive statistics showed that the mean score for Merrill's First Principles problem-centered construct was 8.15, which falls within the moderate range of 7.21 to 10.80 ($Mdn = 8, Md = 7.5, SD = 2.48$). As such, the study concluded that the overall incorporation of the problem-centered principle across courses was moderately integrated. The principle was evident in parts of the courses, though not consistently across all components (Table 5).
<table>
<thead>
<tr>
<th>Principle's Score Range</th>
<th>Integration</th>
<th>Number of Courses in Range</th>
<th>Percentage of Courses in Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 - 3.60</td>
<td><em>Minimal integration.</em> The principle is barely acknowledged or reflected in the course.</td>
<td>2</td>
<td>6.67%</td>
</tr>
<tr>
<td>3.61 - 7.20</td>
<td><em>Low integration.</em> There are some elements of the principle present, but they are limited.</td>
<td>7</td>
<td>23.33%</td>
</tr>
<tr>
<td>7.21 - 10.80</td>
<td><em>Moderate integration.</em> The principle is evident in parts of the course, though not consistently across all components.</td>
<td>17</td>
<td>56.67%</td>
</tr>
<tr>
<td>10.81 - 14.40</td>
<td><em>High integration.</em> The principle is a clear, recurrent theme in the course, significantly shaping content, activities, and assessments.</td>
<td>4</td>
<td>13.33%</td>
</tr>
<tr>
<td>14.41 - 18.00</td>
<td><em>Full integration.</em> The principle is central to the course, thoroughly infused in all aspects, and clearly demonstrated.</td>
<td>0</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

Specifically, ratings for the courses on the individual problem-centered principle ranged between 3.50 (*minimal integration*) and 14.00 (*high integration*). As the data shows, there were no ratings of *full integration* in any of the thirty courses at the university in this study. The online course elements surveyed in this study rarely employed complex, real-world problems. Instead, they often focused on presenting definitions and concepts, with only a few elements connecting them to real-world contexts. Figure 1 illustrates a common finding: an instructor delivered information in a decontextualized manner by solving equations on which the learners would be tested,
expecting learners to absorb much of the content without engaging in authentic, complex problem-solving scenarios. In this instance, the reviewer would have noted this activity did not reflect the problem-centered principle. In other instances, reviewers found elements that did reflect the problem-centered principle. Figure 2 illustrates an element where learners were tasked with using a professional service platform indicative of what they would use in a professional setting to create geographics information systems (GIS) maps in a real-world scenario. In this instance, the reviewer would have noted this activity as reflecting the problem-centered principle, as it challenged learners to solve problems in a real-world context. The overall moderate rating indicates that the courses included a mix of elements, some of which incorporated the problem-centered principle to varying degrees, while others lacked this principle altogether.
Research Question 2: Activation Principle

Research Question 2 measured the degree to which courses integrated activation of existing experience. According to Merrill (2020), the activation principle involves recalling or applying knowledge from relevant past experience as a foundation for new skills. Coders rated this principle using one item, and scores for each course could range...
from 0 to 3 (Table 2). Descriptive statistics showed that the mean score for Merrill's First Principles problem-centered construct was 1.15, which falls within the low range of 0.61 to 1.20 ($Mdn = 1.00, Md = 1.00, SD = 0.33$). As such, the study concluded that the overall incorporation of the activation principle across courses was low. There were some elements of the principle present, but they were limited. (Table 6).

**Table 6**

*Activation Score Range*

<table>
<thead>
<tr>
<th>Principle's Score Range</th>
<th>Integration</th>
<th>Number of Courses in Range</th>
<th>Percentage of Courses in Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 - 0.60</td>
<td>Minimal integration. The principle is barely acknowledged or reflected in the course.</td>
<td>1</td>
<td>3.33%</td>
</tr>
<tr>
<td>0.61 - 1.20</td>
<td>Low integration. There are some elements of the principle present, but they are limited.</td>
<td>21</td>
<td>70.00%</td>
</tr>
<tr>
<td>1.21 - 1.80</td>
<td>Moderate integration. The principle is evident in parts of the course, though not consistently across all components.</td>
<td>6</td>
<td>20.00%</td>
</tr>
<tr>
<td>1.81 - 2.40</td>
<td>High integration. The principle is a clear, recurrent theme in the course, significantly shaping content, activities, and assessments.</td>
<td>2</td>
<td>6.67%</td>
</tr>
<tr>
<td>2.41 - 3.00</td>
<td>Full integration. The principle is central to the course, thoroughly infused in all aspects, and clearly demonstrated.</td>
<td>0</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

Analysis of the activation scores across all thirty courses revealed that 93.33% of the scores fell within the moderate and lower ranges. As in the case of problem-centered
instruction (Research Question 1; Table 5), no courses were found to have full integration of this activation principle. Most course elements reviewed that had the potential to link students to prior knowledge failed to explicitly encourage learners to connect new information with their existing knowledge or experiences. For example, most content introductions, such as the one illustrated in Figure 3, presented new content without explicitly prompting learners to connect the information to prior knowledge or experiences. In this instance, the reviewer would have noted this element does not reflect the activation principle. This example did not ask learners to recall relevant experience, use analogies or metaphors linking new ideas to familiar concepts, or provide any type of self-assessment questions to highlight gaps in understanding. Reviewers found rare course elements that incorporated the activation principle to a higher degree. In one sampled course, a module introduction activated student’s experience by asking them to remember their personal experiences with a solar eclipse before engaging with the material (Figure 4). In this instance, the reviewer would have noted this element as reflecting the activation principle. The overall low rating reflects that the courses predominantly consisted of elements that did not incorporate the activation principle, with only a few elements found reflecting this principle.
Module 6

This module has two lecture videos. These videos cover Chapter 17 of the textbook. Chapter 17 is about Quantum Fields: Relativity Meets Quantum. In Chapter 17 you’ll learn about the necessity of a theory which could combine relativity and quantum physics to describe small scale high speed phenomena. Such a theory was developed during 1930-1950, called quantum field theory. One part of this theory, quantum electrodynamics, is the most accurate scientific theory ever invented.

Watch these videos carefully, pause and take notes and study from your textbook also. You have plenty of time, this module will remain open for two weeks. When you feel like you’re prepared well, you must take Quiz 6. Quiz 6 will be a short quiz, just a 20 points quiz. There will only be 7 multiple choice questions. Quiz 6 will be graded and that grade will be counted to the overall course grade. Note that there will be a limited time window for taking quiz for each student. You can take quiz anytime during the open period, but once you start to take quiz, you’ll get 25 minutes to finish and submit it.

Figure 3

Course Element Not Reflecting Activation Activity

Module 3

This module has two lecture videos and one pdf document. These videos cover Chapter 5 of the textbook. Chapter 5 presents Newton’s Universe. Here we learn about the Newton’s Theory of Gravity and it’s applications to understand the evolution of the Solar System, evolution of the Sun, life and humans, evolution of stars more massive than our Sun etc. Before you begin, take a moment to reflect on any personal experiences you’ve had observing a solar eclipse. How did it make you feel? What questions did it raise for you about the mechanics of our solar system and the forces at play within it? At the end, we also learn about the limitations of Newtonian Physics in light of modern Physics. Pdf document has some numerical problems from Chapter 5. The solutions of those problems are worked out in the document. These problems and solutions will help you a lot when you study.

Watch these videos carefully, pause and take notes and study from your textbook also. You have plenty of time, this module will remain open for two weeks. When you feel like you’re prepared well, you must take Quiz 3. Quiz 3 will be a short quiz, just a 20 points quiz. There will only be 6 multiple choice questions. Quiz 3 will be graded and that grade will be counted to the overall course grade. Note that there will be a limited time window for taking quiz for each student. You can take quiz anytime during the open period, but once you start to take quiz, you’ll get 25 minutes to finish and submit it.

Figure 4

Course Element Reflecting Activation Activity
**Research Question 3: Demonstration Principle**

Research Question 3 measured the degree to which courses reflected the principle of demonstration. Merrill stated, "Learning is promoted when learners observe a demonstration of the skill to be learned that is consistent with the type of skill being taught" (Merrill, 2020, p.4). Courses were scored with four items from the Course Scan instrument, with a possible score between 0 and 10 (Table 2). Descriptive statistics showed that the mean score for Merrill's First Principles demonstration construct was 2.07, which falls within the low range of 2.01 to 4.00 ($Mdn = 2.00$, $Md = 2.00$, $SD = 1.24$). As such, the study concluded that the overall incorporation of the demonstration principle across courses was low. There were some elements of the principle present, but they were limited (Table 7).
Table 7

Demonstration Score Range

<table>
<thead>
<tr>
<th>Principle's Score Range</th>
<th>Integration</th>
<th>Number of Courses in Range</th>
<th>Percentage of Courses in Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 - 2.00</td>
<td>Minimal integration. The principle is barely acknowledged or reflected in the course.</td>
<td>18</td>
<td>60.00%</td>
</tr>
<tr>
<td>2.01 - 4.00</td>
<td>Low integration. There are some elements of the principle present, but they are limited.</td>
<td>11</td>
<td>36.67%</td>
</tr>
<tr>
<td>4.01 - 6.00</td>
<td>Moderate integration. The principle is evident in parts of the course, though not consistently across all components.</td>
<td>1</td>
<td>3.33%</td>
</tr>
<tr>
<td>6.01 - 8.00</td>
<td>High integration. The principle is a clear, recurrent theme in the course, significantly shaping content, activities, and assessments.</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>8.01 - 10.00</td>
<td>Full integration. The principle is central to the course, thoroughly infused in all aspects, and clearly demonstrated.</td>
<td>0</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

Reviewers found that for most course elements with the potential for examples and worked problems, clear, step-by-step demonstrations of problem-solving strategies or procedures were missing or inaccessible. Most often, courses included text information, slides, or multimedia of the instructor delivering lecture information. Figure 5 illustrates a common finding: an archived video of a previous in-person class where an instructor lectured from a podium. Had the instructor worked a problem from beginning to end, the camera's position, the lighting, and the generally low quality of the media meant that the
worked example would have been complicated to see and, therefore, potentially inaccessible to learners in the online environment. In this instance, the reviewer would have noted this element as not reflecting the demonstration because the instructor did not model the desired skills through examples or shared-screen video demonstrations that break down complex tasks into explicitly worked steps. Reviewers found rare course elements that incorporated the demonstration principle. In one sampled course, an instructor worked on a relevant problem from beginning to end, exhibiting each step in order and articulating the process fully (Figure 6). The instructor used a screencast application to record the demonstration from a first-person perspective and recommended that learners pause throughout the videos to work alongside the instructor. In this instance, the reviewer would have noted this element as reflecting the demonstration principle. The overall low rating reflects that the courses predominantly consisted of elements that did not incorporate the demonstration principle, with only a few elements found reflecting this principle.
Figure 5

Course Element Not Reflecting Demonstration Activity

Figure 6

Course Element Reflecting Demonstration Activity
Research Question 4: Application Principle

Research Question 4 measured the degree to which courses reflected the principle of application. Merrill (2020) suggests that learners should have opportunities to apply their new knowledge or skills to solve novel problems. Courses were rated using three items from the Course Scan instrument, with a possible score between 0 and 5 (Table 2). Descriptive statistics showed that the mean score for Merrill's First Principles application construct was 2.52, which falls within the moderate range of 2.01 to 3.00 (\(Mdn = 2.00, Md = 2.00, SD = 1.00\)). As such, the study concluded that the overall incorporation of the application principle across courses was moderate. The principle was evident in parts of the courses, though not consistently across all components (Table 8).
Table 8

**Application Score Range**

<table>
<thead>
<tr>
<th>Principle's Score Range</th>
<th>Integration</th>
<th>Number of Courses in Range</th>
<th>Percentage of Courses in Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 - 1.00</td>
<td>Minimal integration. The principle is barely acknowledged or reflected in the course.</td>
<td>2</td>
<td>6.67%</td>
</tr>
<tr>
<td>1.01 - 2.00</td>
<td>Low integration. There are some elements of the principle present, but they are limited.</td>
<td>15</td>
<td>50.00%</td>
</tr>
<tr>
<td>2.01 - 3.00</td>
<td>Moderate integration. The principle is evident in parts of the course, though not consistently across all components.</td>
<td>5</td>
<td>16.67%</td>
</tr>
<tr>
<td>3.01 - 4.00</td>
<td>High integration. The principle is a clear, recurrent theme in the course, significantly shaping content, activities, and assessments.</td>
<td>6</td>
<td>20.00%</td>
</tr>
<tr>
<td>4.01 - 5.00</td>
<td>Full integration. The principle is central to the course, thoroughly infused in all aspects, and clearly demonstrated.</td>
<td>2</td>
<td>6.67%</td>
</tr>
</tbody>
</table>

Courses included several practice opportunities; most commonly, these activities needed more complexity and variety for deep learning, such as the short answer and multiple-choice test illustrated in Figure 7. While multiple-choice questions can assess memorization and basic conceptual understanding, they often lack the complexity and authenticity of real-world problems. In this instance, the reviewer would have noted this element as not reflecting the application principle. This example did not encourage learners to analyze information or apply their knowledge and make decisions to solve ill-
structured problems, mirroring the challenges they would face in their professional or personal lives. Merrill (2020) states, "Skill development occurs when learners have an opportunity to do it, to apply the skill they have acquired to a variety of specific problems. Remembering information (Ask) is not an application; remembering information seldom prepares learners for applying their skills in real-world situations" (p. 6). In other instances, reviewers found elements that did reflect the application principle. Figure 8 illustrates an activity where students were tasked with the critical appraisal of epidemiological literature that they would have to do in the field. These learners were asked to engage in a realistic exercise with increasingly challenging steps that required them to adapt and transfer their knowledge to a novel situation. Feedback and guidance were provided to help learners refine their skills and correct misconceptions. In this instance, the reviewer would have noted this element as reflecting the application principle. The overall moderate rating indicates that the courses included a mix of elements, some of which incorporated the application principle to varying degrees, while others lacked this principle altogether.
Figure 7

Course Element Not Reflecting Application Activity
Research Question 5: Integration Principle

Research Question 5 measured the degree to which courses reflected the principle of integration. The integration principle involves learners discussing, reflecting on, and defending their new knowledge or skill (Merrill, 2020). The raters used ten items to score courses, and scores for each course could range from 0 to 26 (Table 2). Descriptive
statistics showed that the mean score for Merrill's First Principles integration construct was 3.72, which falls within the minimal range of 0.00 to 5.20 ($Mdn = 2.00$, $Md = 1.00$, $SD = 4.45$). As such, the study concluded that the overall incorporation of the integration principle across courses was minimal. The principle was barely acknowledged or reflected in the courses (Table 9).

Table 9

Integration Score Range

<table>
<thead>
<tr>
<th>Principle's Score Range</th>
<th>Integration</th>
<th>Number of Courses in Range</th>
<th>Percentage of Courses in Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 - 5.20</td>
<td>Minimal integration. The principle is barely acknowledged or reflected in the course.</td>
<td>24</td>
<td>80.00%</td>
</tr>
<tr>
<td>5.21 - 10.40</td>
<td>Low integration. There are some elements of the principle present, but they are limited.</td>
<td>4</td>
<td>13.33%</td>
</tr>
<tr>
<td>10.41 - 15.60</td>
<td>Moderate integration. The principle is evident in parts of the course, though not consistently across all components.</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>15.61 - 20.80</td>
<td>High integration. The principle is a clear, recurrent theme in the course, significantly shaping content, activities, and assessments.</td>
<td>2</td>
<td>2.00%</td>
</tr>
<tr>
<td>20.81 - 26.00</td>
<td>Full integration. The principle is central to the course, thoroughly infused in all aspects, and clearly demonstrated.</td>
<td>0</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

Most courses did not include opportunities for reflection, and most discussion prompts did not promote opportunities for students to defend their viewpoints. In the
STEM courses reviewed, discussion prompts, when they existed at all, routinely asked learners to answer well-structured and conceptual problems with specific questions and post their findings without encouraging learners to synthesize their learning, share insights with others, or consider how they might apply their new knowledge in real-world contexts (Figure 9). In this instance, the reviewer would have noted this element as not reflecting the integration principle. Reviewers found rare course elements that did incorporate the integration principle. In one sampled course, a discussion prompt challenged learners to defend the criteria they used when making a decision on what food-aid program to invest in and to challenge the decisions of their peers throughout the interaction (Figure 10). In this instance, the reviewer would have noted this element as reflecting the integration principle. The overall minimal rating reflects that the courses predominantly consisted of elements that did not incorporate the integration principle, with almost no elements found reflecting this principle.

Figure 9

Course Element Not Reflecting Integration Activity
Research Question 6: First Principles

From a holistic perspective, the College of Arts and Sciences’ asynchronous online STEM courses did not readily apply Merrill’s First Principles of Instruction, with the total mean score per course indicating low integration (Table 10). Courses were scored with a combination of Likert-type scale items and binary items so that scores on the entire scale (e.g., all items) ranged from 0 to 72 so that higher scores indicated greater application of the principles. This score range included the ten points from section two of the instrument, reflecting general organization but not reflecting specific First Principles. Across the total sample of thirty courses analyzed, scores indicated the presence of Merrill’s First Principles across all thirty studies from 6.50 to 45.50 points ($M = 23.50, Mdn = 21.75, Md = 19.00, SD = 8.89$). With an overall mean score of 23.50, the data suggests that the thirty randomly selected courses did not reflect Merrill’s First Principles to a high degree. Tables 10 and 11 below provide a more detailed view of the score ranges across the thirty courses analyzed.
### Table 10

**Total Score Descriptive Statistics Across Thirty Courses**

<table>
<thead>
<tr>
<th></th>
<th>Total Score (out of 72)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N</strong></td>
<td>30.00</td>
</tr>
<tr>
<td><strong>M</strong></td>
<td>23.50</td>
</tr>
<tr>
<td><strong>Mdn</strong></td>
<td>21.75</td>
</tr>
<tr>
<td><strong>Md</strong></td>
<td>19.00</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>8.89</td>
</tr>
<tr>
<td>Minimum</td>
<td>6.50</td>
</tr>
<tr>
<td>Maximum</td>
<td>45.50</td>
</tr>
</tbody>
</table>

### Table 11

**Total Score Range Across Thirty Courses**

<table>
<thead>
<tr>
<th>Principle's Score Range</th>
<th>Integration</th>
<th>Number of Courses in Range</th>
<th>Percentage of Courses in Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 - 14.40</td>
<td>Minimal integration. The principle is barely acknowledged or reflected in the course.</td>
<td>2</td>
<td>6.67%</td>
</tr>
<tr>
<td>14.41 - 28.80</td>
<td>Low integration. There are some elements of the principle present, but they are limited.</td>
<td>21</td>
<td>70.00%</td>
</tr>
<tr>
<td>28.81 - 43.20</td>
<td>Moderate integration. The principle is evident in parts of the course, though not consistently across all components.</td>
<td>5</td>
<td>16.67%</td>
</tr>
<tr>
<td>43.21 - 57.60</td>
<td>High integration. The principle is a clear, recurrent theme in the course, significantly shaping content, activities, and assessments.</td>
<td>2</td>
<td>6.67%</td>
</tr>
<tr>
<td>57.61 - 72.00</td>
<td>Full integration. The principle is central to the course, thoroughly infused in all aspects, and clearly demonstrated.</td>
<td>0</td>
<td>0.00%</td>
</tr>
</tbody>
</table>
From these findings, 76.67% of the thirty courses only demonstrated low or minimal inclusion of Merrill’s First Principles of inclusion. 16.67% of the courses reviewed included moderate integration. 6.67% of courses reviewed indicated high integration, and zero of the courses reviewed included full integration.

**Summary**

The results demonstrated that the design of the College of Arts and Sciences' asynchronous online STEM courses predominantly reflects Merrill’s First Principles of Instruction to a low extent. Total scores out of a possible 72 points ranged from 6.50 to 45.50, with a mean of 23.50, indicating low alignment with evidence-based instructional criteria across the sample of thirty analyzed courses. While the individual problem-centered and application construct demonstrated moderate integration, the activation and demonstration principles indicated low integration, and the integration principle demonstrated minimal integration. A succinct summary of the individual principle descriptive statistics can be found in Table 12, and descriptive statistics of individual Course Scan items can be found in Appendix B.

**Table 12**

*Individual Principle Descriptive Statistics*

<table>
<thead>
<tr>
<th>Principle</th>
<th>$M$</th>
<th>$Md$</th>
<th>$Md$</th>
<th>$SD$</th>
<th>Range</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Maximum Possible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem-Centered</td>
<td>8.2</td>
<td>8</td>
<td>8</td>
<td>2.5</td>
<td>10.5</td>
<td>3.5</td>
<td>14.0</td>
<td>18</td>
</tr>
<tr>
<td>Activation</td>
<td>1.2</td>
<td>1</td>
<td>1</td>
<td>0.3</td>
<td>1.5</td>
<td>0.5</td>
<td>2.0</td>
<td>3</td>
</tr>
<tr>
<td>Demonstration</td>
<td>2.1</td>
<td>2</td>
<td>2</td>
<td>1.2</td>
<td>4.5</td>
<td>0.0</td>
<td>4.5</td>
<td>10</td>
</tr>
<tr>
<td>Application</td>
<td>2.5</td>
<td>2</td>
<td>2</td>
<td>1.0</td>
<td>3.5</td>
<td>1.0</td>
<td>4.5</td>
<td>5</td>
</tr>
<tr>
<td>Integration</td>
<td>3.7</td>
<td>2</td>
<td>1</td>
<td>4.5</td>
<td>18</td>
<td>0.0</td>
<td>18.0</td>
<td>26</td>
</tr>
</tbody>
</table>
CHAPTER FIVE: DISCUSSION AND CONCLUSIONS

Merrill’s First Principles of Instruction provide an empirically supported framework of effective instructional design strategies that promote learning. However, there is a lack of research examining the extent to which these principles are applied in the design of online STEM courses at public universities. To address this gap, this study assessed the extent to which asynchronous online STEM courses at a public university incorporate Merrill's First Principles of Instruction. The research questions were:

Research Question 1. To what extent, if at all, does the design of the College of Arts and Sciences’ asynchronous online STEM courses reflect the First Principles of Instruction?

Research Question 1. To what extent, if at all, are the College of Arts and Sciences’ asynchronous online STEM courses problem-centered?

Research Question 2. To what extent, if at all, do the College of Arts and Sciences’ asynchronous online STEM courses demonstrate activation of existing experience?

Research Question 3. To what extent, if at all, do the College of Arts and Sciences’ asynchronous online STEM courses reflect the principle of demonstration?

Research Question 4. To what extent, if at all, do the College of Arts and Sciences’ asynchronous online STEM courses enable learners to apply their new knowledge or skill to solve problems?

Research Question 5. To what extent, if at all, do the College of Arts and Sciences’ asynchronous online STEM courses encourage learners to integrate new knowledge or skill?
Research Question 6. To what extent, if at all, does the design of the College of Arts and Sciences’ asynchronous online STEM courses reflect the First Principles of Instruction?

The findings of this quantitative content analysis provide important insights into the current state of online course design quality in STEM disciplines at a public university. This chapter summarizes the key results found and discusses implications, limitations, and opportunities for future research to enhance instructional strategies at the university.

Implications for Practice

Merrill's First Principles of Instruction relates to several instructional approaches that continue to be extensively studied in education research. While debate on these educational approaches continues, research literature consistently highlights the benefits of these strategies for learners. However, the findings of this study and related articles demonstrate that their actual implementation in educational settings still needs to be improved. The following sections explore recent research literature for potential reasons for this gap and recommendations for high-quality implementation.

Research Question 1: Problem-Centered Principle

Inquiry-based learning and problem-centered strategies (e.g., case-based learning, project-based learning, experiential learning) have been widely discussed and researched in education over several years, with research literature demonstrating consistent significance to learners. Moreover, contemporary educational benchmarks, such as the Next Generation Science Standards (NGSS) and the Integrated STEM (iSTEM) model, have adopted instructional strategies consistent with problem-centered and inquiry-based
learning elements (Robinson et al., 2014; Spikic et al., 2023). For example, the iSTEM model contains problem-based principles to help integrate the content and skills across different STEM disciplines by posing real-world challenges, as well as inquiry-based learning by posing complex questions and allowing learners to process problems by examining, gathering information, and interpreting the information (Spikic et al., 2023). These principles align with fundamental concepts of constructivism which states that learning is largely experiential, so it follows that knowledge would be promoted through experienced, problem-centered activities (Ertmer & Newby, 2013). “Psychologists and educators began to de-emphasize a concern with overt, observable behavior and stressed instead more complex cognitive processes such as thinking, problem solving, language, concept formation and information processing” (Ertmer & Newby, 2013, p. 57). In terms of learning outcomes, comprehensive reviews of scholarly articles continue to acknowledge their positive influence in terms of improved problem-solving and critical-thinking skills (de Jong et al., 2023; Tawfik & Trueman, 2015), self-directed learning skills (Leary et al., 2019), increased motivation and interest in learning (Cairns & Areepattamannil, 2019) as well as higher self-efficacy in learners (Hung, 2011; Liu & Wang, 2022; Tawfik, Gish-Lieberman, Gatewood, & Arrington, 2021).

This research builds on the broader conversations around problem-centered instruction as it explores how it is applied comprehensively within an online learning STEM context. Results from this study found that 56% of the courses reviewed demonstrated moderate integration of the problem-centered principle, suggesting that the principle was somewhat evident in parts of the course, though not consistently across all coded components. Despite some integration at a moderate level, almost a quarter of
courses reviewed fell into a minimal or low integration range, suggesting that the principle was barely acknowledged or reflected in the course or that there were a few elements of the principle present in a limited fashion. Only 13.33% of courses surveyed included high integration, showing a clear and recurrent theme of problem-centered elements in the course, significantly shaping content activities and assessments. None of the courses surveyed included full integration, which would indicate the problem-centered principle as central to the course and infused in all aspects. Research by Margaryan et al. (2015) and Chukwuemeka et al. (2015) demonstrated similar results of problem-centered elements in a sample of open education courses that were analyzed using the First Principles of Instruction framework. For example, Margaryan et al.’s (2015) results found that only 8 of the 76 total MOOCs sampled included problem-centered activities, while Chukwuemeka et al.’s (2015) results indicated 33.3% of courses sampled included real-world problems to some extent, and 44.4% did not include any real-world problems.

Despite the efficacy and value of problem-based methodologies underscored by scholarly research, their comprehensive implementation across educational settings remains low. Although there is a gap in research directly addressing the discrepancies between recommended practices and their real-world application, recent research in these domains may shed light on potential contributing factors. Indeed, the results align with broader research on problem-centered instruction, on the challenges of a case-driven approach to education whereby students are afforded agency to solve complex, ill-structured problems (Chukwuemeka et al., 2015; Margaryan et al., 2015). Implementing problem-centered elements, especially to a full extent, can be challenging from a design
and implementation perspective. As noted by Rees Lewis et al. (2019), problem-centered activities are complex and involve a number of variables that an instructor or instructional designer must contend with. Law et al. (2020) elaborate on this point and note that “Several dimensions need to be considered in the design of problem scenarios: the complexity of problems, the size of the problem space, level of ill-structuredness or authenticity, and student autonomy” (Law et al., 2020, p. 329). Given these design complexities of problem-centered instruction, research by Fitzgerald et al. (2019) identified the primary concern among educators when integrating inquiry-based activities as a lack of time, with instructional development and innovative teaching strategies often sidelined due to the focus on teaching and research duties. Other deterrents include insufficient support, familiarity, and instructor confidence in problem-centered learning approaches as being effective. The research suggests that implementing a well-conceived, problem-centered, ill-structured scenario can thus be a greater challenge compared to traditional instructional activities (Fitzgerald et al., 2019).

Beyond just the design of the case that drives problem-centered instruction, the strategy also includes other critical pedagogical aspects related to (a) assessment and (b) student support. In terms of the former, assessment of complex, real-world, ill-structured problems also presents a significant challenge for educators, given the absence of definitive right or wrong answers. Educators are tasked with evaluating multifaceted student solutions at various stages of a problem-centered task (C. Chen & Yang, 2019). Educators may be apprehensive about assigning inconsistent grades to students who present a diverse array of solutions (van der Vleuten & Schuwirth, 2019; Zhou et al., 2023). More recently, various solutions have been proffered to address the assessment
challenges using artificial intelligence and machine learning, but the research is still relatively new (Giabbanelli & Tawfik, 2019, 2020; Wang & Giabbanelli, 2023). The research suggests that the assessment challenges of problem-centered instruction still remain, which may further explain the results presented in Chapter Four.

Within the context of the current study, the online environment may introduce additional barriers to implementation in terms of learner-instructor interactions as the class engages in complex problem-solving. Opportunities for feedback and guidance may be slower in asynchronous settings (Law et al., 2020). Facilitation and demonstration of complex, problem-centered activities require considerably more planning and intentionality, and the technology resources available must be understood by instructors to be fully utilized. Complex reasoning processes require opportunities to challenge learners with questions, provide feedback, and engage failure (Cai & Moallem, 2021). While these elements can flow more naturally in a conversation narrative facilitated by a synchronous online modality, studies find that asynchronous modalities where learners are engaging at different times may be challenging and require instructors to plan ahead (Shek et al., 2021).

**Learning Design Implications to Support Problem-Centered Instruction**

Merrill (2020) builds the First Principles of Instruction around the central concept that task-focused, problem-centered experiences provide greater value for learners, that students learn from and relate to working through practical challenges. Recent research literature highlights several techniques instructors could use to enhance problem-centered learning. Additionally, there is a recommendation for improving the Course Scan
instument to better assess the implementation of problem-centered learning in online courses. Recommendations include:

- Partnering with instructional designers, allowing instructors to become experienced with strategies for designing scaffolded, ill-structured problem scenarios with diverse solutions (Fitzgerald et al., 2019; Law et al., 2020).

- Leveraging technology to encourage engagement and feedback by partnering with instructional technologists and media experts, providing instructors with immediate access to expert knowledge and support, and reducing the learning curve and time investment needed to integrate tools (Cai & Moallem, 2021; Law et al., 2020).

- Adopting flexible assessment strategies, including detailed rubrics that have multiple problem-solving competencies (e.g., question generation, hypothesis generation, argumentation, decision-making, etc.) rather than simple, final solutions (C. Chen & Yang, 2019; van der Vleuten & Schuwirth, 2019).

- Instrument Recommendations: Provide specific metrics, examples, and locations for evidence of the problem-centered principle. For instance, examples of real-world scenarios and ill-structured tasks in the course syllabus, learning objectives, instructional materials, and assignments.

**Research Question 2: Activation Principle**

Activating prior knowledge continues to be a learning strategy supported by research literature. A large-scale overview by Law et al. (2020) suggests that activation
of prior knowledge is a critical pedagogical element, especially in problem-centered contexts, as learners must draw on prior knowledge to represent or frame a problem and generate a solution. If prior knowledge is lacking or is not activated, learners may have difficulty identifying important, fundamental aspects crucial to engaging in the complex processes required to solve the problem (Law et al., 2020). Indeed, when presented with a problem to solve, learners must be able to "explore the problem space and connect their prior knowledge in an attempt to develop an understanding of the problem" (Law et al., 2020, p. 323). The concept of activating prior knowledge is closely linked and often operationalized with the concept of scaffolding, which focuses on meeting learners at their current level of understanding (Guo, 2022; Schumacher & Stern, 2023). A large-scale meta-analysis by Kim et al. (2020) revealed that scaffolding within problem-centered instruction, particularly in STEM education, had beneficial effects, whether implemented in individual or group settings. This research also proposed that different types of scaffolding, such as conceptual, metacognitive, strategic, and motivational, may perform differently but were all helpful when used in problem-solving settings (Kim et al., 2020). Collectively, the research suggests that activation and scaffolding are multifaceted aspects of supporting problem-centered instruction.

In this study, 73.33% of all courses reviewed demonstrated low or minimal integration, suggesting that the activation principle was barely acknowledged or reflected to a limited degree through the courses. Six of the thirty sampled courses demonstrated moderate integration, with examples of activation evident in some parts but not consistently throughout the course. Only two of the thirty courses (6.67%) demonstrated high integration, and none of the sampled courses demonstrated full integration. These
results align with other research that found similarly low levels of methods to activate existing experience in learners (Chukwuemeka et al., 2015; Margaryan et al., 2015). As with the problem-centered principle, the data from Research Question 2 suggests a discrepancy between the recommendations of activation as a high-impact instructional strategy and its actual, consistent implementation.

Many of the same challenges discussed earlier regarding the problem-centered principle (RQ1), including the complexity of implementation, may help to explain the low extent of adoption of the activation principle. For example, potential impediments, such as (a) the nuanced process of facilitating scaffolding and (b) how to activate/scaffold across multiple resources.

Law et al.’s (2020) work speaks to the complex nature of scaffolding of ill-structured problems, suggesting that facilitators must simultaneously possess deep subject knowledge, the capacity and willingness to authentically engage with learners, and an understanding of the individual attributes learners bring to the problem. Given these recommendations and the limited availability of time for implementation and facilitation, instructors might choose to have learners over-rely on their own processes for activating prior knowledge rather than developing formal processes for activation (Fitzgerald et al., 2019). Since activation involves meeting students where they are in terms of knowledge gaps and limited experience, providing just-in-time information is a valuable approach (Law et al., 2020). However, this approach further complicates implementation as it requires time and resources as instructors must develop not only the core course content but also supplementary, optional materials that may be needed by some learners but unnecessary for others. A related argument by Ostermann (2018) suggests that instructors
may find it difficult to anticipate what information a new learner may need. Coined as the expert blind spot, this phenomenon refers to an expert’s potential difficulty in putting themselves in the position of a novice and anticipating what information they may need (Ostermann, 2018). This concept may explain a lack of adoption by instructors who do not fully understand what information learners may need to be explained or activated before new knowledge is presented (Ostermann, 2018). In terms of course design, instructors may focus primarily on the conceptual components that need to be acquired, inadvertently overlooking gaps in learners' prior knowledge and missing opportunities to effectively leverage the activation principle.

In addition to the challenges posed by the expert blind spot, instructors must also consider the diverse range of resources that may contribute to a course. Lundstrom et al.’s (2015) research suggested that while an expert may more easily recognize similarities, differences, and relationships to the problem or domain across disparate resources, a novice learner may not be able to synthesize connections or key ideas across different learning resources. Lundstrom et al.’s work found that “students struggle with synthesis and benefit from teaching methods that break down the different skills involved in synthesis” (Lundstrom et al., 2015, p. 72). Related work by Yukhymenko-Lescroart et al. (2020) builds on these concepts, finding that synthesis becomes harder as complexity increases in terms of finding and accessing relevant resources. In terms of supporting this challenge, a systematic literature review conducted in (2024) by Hattan et al. examined the body of literature on prior knowledge and its activation, acknowledging its potential to enhance learner understanding while admitting that the concept of activation is often ambiguously defined and poorly comprehended by educators. These findings support the
idea that, for new learners, instructors should carefully evaluate how each resource fits into their approach to activation, not only at the individual resource level but also holistically throughout the module or unit.

**Learning Design Implications to Support Activation Principle**

Merrill (2020) suggests that learners benefit from activating existing experiences and knowledge and that instructors should scaffold authentic experiences based on where a learner is and then build to new, complex problems. This body of research highlights several techniques instructors could use to enhance the activation principle further. Additionally, there is a recommendation for improving the Course Scan instrument to better assess the implementation of activation in online courses. Recommendations include:

- Provide just-in-time resources, such as interactive knowledge checks with targeted material and contextual resources, allowing learners to access material as needed based on their current level of understanding (Law et al., 2020; Ostermann, 2018).

- Incorporating synthesis skills and assessment techniques, assisting new learners with their ability to integrate information from disparate resources (Lundstrom et al., 2015; Yukhymenko-Lescroart et al., 2020).

- Provide pre-assessments or practice exercises early to cultivate instructor awareness of what resources learners need, combatting the potential expert blind spot (Nathan & Koedinger, 2000; Ostermann, 2018).
• Instrument recommendations: Provide specific criteria, examples, and practical locations for evidence of the activation principle. For instance, examples of prior knowledge assessments, reflection prompts, and real-world examples that connect new learners’ experiences in the module introductions, discussion forums, and learning activity instructions.

**Research Question 3: Demonstration Principle**

Merrill (2020) suggests that demonstration fundamentally involves showing learners how to perform tasks, allowing them to observe the processes involved in solving a problem or mastering a skill rather than merely explaining these processes. The concept of demonstration is often applied through modeling, case libraries, and others. Modeling (often in the form of multimedia) illustrates skills that are beyond the current capabilities of the learner (Janssen et al., 2023), while a case library enriches the demonstration by offering narratives that depict how experts have addressed similar problems (Tawfik et al., 2019).

In this study, 96.67% of all courses reviewed demonstrated low or minimal integration, with 60% in the minimal range, suggesting that the demonstration principle was rarely implemented. Only one course reviewed was considered to have moderate integration, and none of the thirty surveyed courses included high or full integration. This study found numerous instances of multimedia usage, sometimes in the form of intentionally recorded lectures but often as archived broadcast recordings from previous in-person classes. However, these multimedia elements seldom incorporated demonstration, modeling, or worked examples. One potential explanation could be attributed to the STEM field courses included in this study. While recording lectures may
be more accessible, creating detailed demonstrations that accurately represent the nuances of complex, ill-structured, real-world problems in sciences, technology, engineering, and mathematics disciplines may still demand expertise beyond what a typical instructor possesses (Fitzgerald et al., 2019; Hu et al., 2021; Ibáñez & Delgado-Kloos, 2018). From a design perspective, these challenges might require subject-matter experts to partner with instructional design experts and multimedia experts capable of creating demonstrations of complex activities in a clear and well-segmented way.

These results align with research, which consistently showed low integration of the demonstration principle (Chukwuemeka et al., 2015; Margaryan et al., 2015). Considering the substantial body of research that underscores the advantages of demonstration and the wide range of techniques available, there is a discrepancy in the application of demonstration techniques in the evaluated courses. Recent studies that introduce high-quality, well-segmented demonstrations often had assessment specialists and digital media specialists assisting the instructor to achieve positive results (Chong, 2019; Hu et al., 2021; Noetel et al., 2022). While a broad spectrum of pre-existing resources is available online or through publishers, the unique nature of problem-based, ill-structured activities with multiple potential outcomes makes it difficult to find pre-made resources that are clear, relevant, and suitable.

**Learning Design Implications to Support Demonstration Principle**

Merrill’s (2020) demonstration principle suggests that problem-centered learning is enhanced when new knowledge is demonstrated to learners in a clear, consistent, and accessible format. Research suggests ways for instructors to improve fundamental
demonstration techniques. Also, there is a recommendation for improving the Course
Scan instrument to better assess the implementation of demonstrations in online courses.
Recommendations include:

- Demonstrate poor techniques and expert failures to foster resiliency (Lin-Siegler et al., 2016; Rong & Choi, 2019).
- Adopt interactive simulations and incorporate "pause and apply" prompts
during demonstrations to enable learners to practice skills in real time,
fostering the immediate application of demonstrated steps for improved
learning outcomes (Mayer et al., 2020; Tuncer et al., 2021).
- Integrating pause and do periods through demonstrations, allowing
learners to engage with the problem alongside the demonstration instead
of after (Mayer et al., 2020; Tuncer et al., 2021).
- Incorporating a case library allowing novice learners access to a range of
supplemental cases detailing how experts approach similar complex
problems (Lin-Siegler et al., 2016; Tawfik et al., 2019).
- Prioritizing using first-person perspectives in video demonstrations of
manual and digital tasks. This will allow learners to enhance their
involvement and efficacy and foster a deeper sense of engagement and
understanding (Mayer et al., 2020).
- Instrument recommendations: Provide specific benchmarks, examples, and
expected course locations for evidence of the demonstration principle. For
instance, it may not make sense to seek instances of worked examples,
expert modeling, and multiple representations of concepts in an interactive
discussion board, instead focusing on the instructional videos, lecture notes, and content areas.

**Research Question 4: Application Principle**

Early research in this field emphasized the importance of applying newly acquired knowledge to solve problems, which is closely related to aspects of learner agency within constructivism. In this study, the application principle's integration in the thirty sample courses was more widely dispersed than other principles. 56.67% of the courses reviewed fell in the low or minimal integration, demonstrating that the principle was rarely reflected in these courses. 43.34% of courses fell into the moderate, high, or full integration ranges. No other principle was found to have a single course in the full integration range beyond the application principle, which found that two courses (6.67%) had the application principle central to the course, infused through all aspects, and clearly demonstrated. These findings align with Margaryan et al.'s (2015) research, which found that only 6% of content-based MOOCs largely employed application principles. Chukwuemeka et al.’s (2015) results also showed that the extent to which the application principle was integrated was low but similarly dispersed across the sampled courses. These studies suggest that learners are not provided with hands-on practice opportunities to apply their new knowledge and skills. This is an issue as analogical, and learning transfer are key aspects that show that learners are able to apply their knowledge to new problems. As stated by Gick and Holyoak (1983), “This ability is used to construct new scientific models, to design experiments, to solve new problems in terms of old ones, to make predictions, to construct arguments, and to interpret literary metaphors” (Gick & Holyoak, 1983, p. 1). This mapping and transfer process is crucial when comparing two
specific analogs and when comparing an analog to a more general schema (Gick & Holyoak, 1983). Their findings shed light on the cognitive processes involved in applying knowledge to solve new problems, the core characteristic of Merrill’s application principle.

Merrill (2020) suggested that application to new problems is particularly beneficial for novice learners when it is accompanied by detailed feedback and support, which should gradually decrease as learners gain the ability to perform new skills independently. These findings around this principle may relate to the broader debates about learner agency in problem-centered instruction (Hmelo-Silver et al., 2007). More recent arguments by Zhang et al. (2022) have questioned the evidence of inquiry-based methods in all contexts, suggesting that direct instruction may be more appropriate for beginners and the degree to which they should apply their knowledge towards novel problems. Conversely, de Jong et al. (2023) defended the position that inquiry-based, problem-centered instruction yields superior outcomes because the approach allows learners an active role in their learning. The authors of both studies acknowledged the complexity of the different approaches, noting that effectiveness depends on various factors such as prior knowledge activation and that application proves most effective when learners receive the necessary support and scaffolding. That is, multiple aspects of first principles must align for problem-centered instruction to be effective. Gardner et al. (2020) provide further insight into the challenges of implementing application elements. In an evaluation course, Gardner observed that a common sequence of instruction was read-listen-assess, and “. . . students were not given opportunities to practice and apply the key skills of conducting an instructional evaluation” (Gardner et al., 2020, p. 499).
These studies support Merrill's recommendation to include authentic, real-world tasks for students to apply their new knowledge to the environment. However, offering these application opportunities should involve a holistic approach to design, providing a balanced mix of feedback and direct assistance tailored to each learner's skill level. Structuring these application activities may require significant effort from instructors, who are advised to start with smaller tasks and gradually expand their scope, as well as by learning from experienced educators who have successfully implemented full-scale application initiatives (Fitzgerald et al., 2019).

Learning Design Implications to Support Application Principle

Merrill (2020) suggests that learners benefit from applying new knowledge to novel problems, giving learners opportunities to solve real-world problems and overcome challenges firsthand. This body of research highlights several techniques instructors could use to enhance the application principle. Additionally, there is a recommendation for improving the Course Scan instrument to better assess the implementation of the application principle in online courses. Recommendations include:

- Provide multiple analogs, allowing students more opportunities to build a schema that can be applied to solve novel problems (Gick & Holyoak, 1983).
- Scaffold problem-centered activities to the learner’s expertise level, allowing novice learners more explicit analogies (Goldwater et al., 2021).
- Instrument recommendation: Provide specific metrics, examples, and locations for evidence of the application principle. For instance, examples
of practice opportunities, scaffolded tasks, and complex, real-world projects in the quizzes, assignments, labs, and capstone projects.

Research Question 5: Integration Principle

Merrill's concept of integration involves educational strategies operationalized as reflection, discussion, and the defense of newly acquired knowledge or skills when challenged (Margaryan et al., 2015; Merrill, 2020). A substantial body of research attests to the positive impact of reflection and other integrative practices, highlighting how reflection enables both instructors and learners to identify knowledge gaps and finalize mental models (B. Chang, 2019; Gorski & Dalton, 2020; Guo, 2022; Zhai et al., 2023). However, the actual implementation of integration principles in online courses, as revealed in this study, is scarce, mirroring findings from other research that demonstrated a minimal presence of integration activities (Chukwuemeka et al., 2015). Margaryan et al.'s (2015) study of MOOCs found low reflection, with only five of the 76 courses studied containing integration activities and only one in non-constructivist MOOCs. Likewise, this current study found 93.33% of courses sampled to be in the low or minimal integration range, with 24 out of 30 sampled courses falling into the minimal range, suggesting these courses barely reflected the principle.

Current research might shed light on the discrepancy between theoretical support for integration strategies and their consistent lack of practical application. The inconsistency in understanding and applying integration, including reflective practices, may stem from the varied interpretations of terms and techniques across educational contexts, along with the lack of established reflection models to support problem-centered instruction. Rong and Choi (2019) argue that cognitive failure cases, which
expose errors in thinking and reasoning processes, can encourage reflection on the causes of failure and promote the development of problem-solving skills. DunnGalvin et al. (2019) highlighted the need for more conclusive evidence regarding effective reflective practices, particularly in the medical field, emphasizing the challenge of developing valid and reliable assessments for reflective activities. More recently, Gorski and Dalton (2020) advocate for complex reflections that encompass societal and environmental perspectives, moving beyond simple, internal reflections that may inadvertently reinforce personal biases and experiences. In terms of the current case study, online environments offer unique opportunities and challenges for integration, with asynchronous formats providing more time for individual reflection before posting. That is, learners have more time between messages in an asynchronous discussion forum than in a live classroom or synchronous setting. Technological tools such as the Video Annotation Tool (VAT) described by Shek et al. (2021) could enhance reflection in media-rich asynchronous online courses. These systems enable learners to momentarily pause asynchronous video content to annotate reflections at specific timestamps. These reflective insights can subsequently be shared amongst the instructor and peers, thereby augmenting the media with a collective of multiple learner experiences (Shek et al., 2021).

**Learning Design Implications to Support Integration Principle**

At the fundamental level, a course with well-designed integration should include explicit opportunities for learners to demonstrate their new knowledge and defend what they have learned, and intentional reflection activities allowing learners to appreciate progress and transfer new knowledge to their personal lives (Merrill, 2020). These studies
suggest several techniques instructors could use to improve the integration principle. Additionally, there is a recommendation for improving the Course Scan instrument to better assess the implementation of integration in online courses:

- Enhance reflection opportunities with VAT systems for media, allowing learners to build collaborative, shared experiences around asynchronous course activities (Shek et al., 2021).

- Utilize social media platforms while being mindful of privacy, allowing learners to connect course experiences with real-world applications (S. L. Chang & Kabilan, 2022).

- Provide detailed explanations and clarifications of the terminology used, highlighting for learners the significance and benefits of reflective practices (DunnGalvin et al., 2019).

- Instrument recommendations: Provide specific criteria, examples, and locations for evidence of the integration principle. For instance, examples of reflection assignments and opportunities to challenge and defend ideas in the course conclusion, discussion boards, portfolios, and self-assessment activities.

**Limitations and Future Research**

While the study utilized validated quantitative methodologies to examine course design, there were limitations related to replicability and generalization of results. The sample consisted only of STEM courses offered by a single college in a mid-sized higher education university. As noted above, future research could examine courses across multiple institutions for more comprehensive and comparative data. This research would
be beneficial and advance research on First Principles because it might discover how different institutional contexts influence the adoption of these instructional strategies, revealing patterns that can inform educational practices. For example, it might be found that community colleges focusing on vocational training implement the principles differently than research-intensive universities, where theoretical understanding might be emphasized. Courses across different disciplines could also be analyzed to determine if integration of any of Merrill’s First Principles is applied more frequently or consistently.

Similarly, content analysis cannot fully capture the dynamic nature of the learning experience (Huxley, 2020). This study focused on evaluating the course copies without student communication or submissions, which provide a structural framework but may only reflect some of the interactive elements and supplementary resources incorporated by instructors during the course implementation. It is possible that some of Merrill's First Principles were more meaningfully integrated through ongoing interactions between students and faculty, as well as additional materials and activities posted as part of discussions. While the course copies themselves may appear to have limited application of the First Principles, it is important to acknowledge that the actual course experience could involve a higher level of adherence to these principles. Instructors may enhance the course with additional information, real-world examples, and opportunities for practice and feedback during learner interactions that are not explicitly outlined in the copied content. They may also facilitate discussions, collaborative projects, and reflective activities that foster a more engaging and interactive learning environment, which might impact constructs such as demonstration, activation, and integration.
A mixed-methods approach could be used to better understand the application of First Principles in online STEM courses. Integrating qualitative data, such as student perceptions gathered through reflections, surveys, or interviews, could provide valuable insights into the effectiveness of the first principles. Enhancing quantitative content analysis with qualitative data sources would develop a more nuanced and holistic view of how Merrill's First Principles are implemented in the context of online learning (Creswell & Creswell, 2017). The low implementation in this and similar studies raises important questions about the quality and effectiveness of online educational offerings, particularly in STEM fields that rely heavily on active learning and practical application (Lou et al., 2011; Spikic et al., 2023). Further research on strategies to integrate evidence-based instructional design in online courses could enhance student learning experiences and outcomes.

Measuring course design quality relies on the reviewer's instructional design expertise (Bratton, 1983; Ritzhaupt & Kumar, 2015). However, not having subject-matter experts as part of the review process is a limitation that may affect the accuracy of the findings, particularly domain-specific aspects (Tessmer & Wedman, 1992). For example, an instructional design expert reviewing a STEM course might not fully appreciate the real-world relevance of an ill-structured problem related to biochemistry or environmental legislation. In this study, the reviewers attempted to differentiate between generic and domain-specific problem-solving instances based on their instructional design expertise. Future research could benefit from including both instructional design experts and SMEs in the review process to ensure a more comprehensive evaluation of course design quality (Ritzhaupt & Kumar, 2015; Tessmer & Wedman, 1992).
While the Course Scan instrument provided a structured framework for evaluating the integration of Merrill’s First Principles in online courses, the specific criteria were limited. The instrument used a series of items asking holistic questions to assess the overall implementation of each principle within the course. However, it lacked explicit criteria for determining when an individual course element, such as a specific learning activity or resource, counted as reflecting a principle. The instrument would benefit from more detailed specifications on what constitutes evidence of each principle at the level of individual course components. For instance, guidelines or examples could be provided on the markers and characteristics for resources that effectively incorporate activation. The instrument could also offer more guidance on where to look for evidence of each principle within the course structure. This direction could help minimize the potential for elements not typically associated with a particular principle to influence the overall assessment negatively. While instructional designers can use their expertise to make informed judgments, an instrument with well-defined criteria for individual elements would add consistency to the evaluation process.

**Conclusion and Summary of Findings**

Overall, the study revealed a low extent of implementation of Merrill's First Principles of Instruction across the evaluated sample of online asynchronous STEM courses. While courses included moderate problem-centered and application strategies, incorporation of demonstration, activation, and integration principles was low to minimal. The problem-centered (RQ1) and application (RQ4) principles were the most readily integrated across the observed courses. The sampled courses included real-world, relevant activities and opportunities for learners to apply new knowledge to real-world
problems to a moderate extent (Merrill, 2020). Other principles, such as the activation (RQ2), demonstration (RQ3), and integration (RQ5) principles, had a low to minimal presence in these thirty random courses. These findings indicate that the courses sampled included few demonstrative or interactive practice opportunities that allow learners to apply skills with explicit instructor feedback and guidance and did not typically integrate prior knowledge activation, peer collaboration, and reflection to deepen learning. These findings reveal clear opportunities for growth in this university’s application of Merrill’s instructional principles.

**Conclusion**

While situated at one public university, this research provides a replicable model for data-driven quality assurance initiatives across institutions. The analysis techniques used in this and in other studies (Chukwuemeka et al., 2015; Margaryan et al., 2015) provide an example method to evaluate online course design quality in a scalable way. Other higher education institutions can adapt this study's methodology to quantify alignment with the extent of Merrill’s First Principles. Results could pinpoint areas of excellence versus deficiency in the online design of courses. Moreover, comparative research across multiple institutions may be conducted. Evaluating online courses across institutions would allow an understanding of broader online course quality issues in different contexts, regions, or with various student populations. Regional or discipline-specific studies could present opportunities for enhancing design aligned with evolving workforce needs.

Educational strategies such as those encompassed in Merrill's First Principles of Instruction are largely cited as effective and beneficial by research. However, this study
demonstrates low integration in online courses, which aligns with the research literature (Chukwuemeka et al., 2015; Margaryan et al., 2015). The gap between theoretical advocacy and practical adoption in online learning environments could be attributed to several factors, including the challenge of altering teaching and learning cultures, the complexity of developing and evaluating ill-structured problems, and the technical expertise and time required to offer meaningful demonstrations and feedback for problem-centered activities. While these barriers are subject to speculation, a definitive explanation for the limited application of these instructional principles still needs to be discovered. Future research endeavors could clarify the reasons behind this phenomenon and identify strategies to promote wider adoption and better implementation of Merrill's First Principles of Instruction in online environments.
References


https://doi.org/10.1080/14703297.2020.1813187

https://doi.org/10.1007/s11528-021-00624-6

https://doi.org/10.1007/s11528-017-0215-z


https://doi.org/10.1891/0889-8391.13.2.158

https://doi.org/10.1177/2332858419876252


https://doi.org/10.1080/10494820.2017.1421561

https://doi.org/10.1080/10495142.2014.901004

https://edtechbooks.org/ux/participatory_and_co_design


https://www.proquest.com/openview/3283073cbfeb93d328d0f96e49be15d2/1?pq-origsite=gscholar&cbl=41798


https://doi.org/10.1016/j.edurev.2023.100536

https://doi.org/10.1016/j.compedu.2005.04.005


Gagné, R. M. (1985). *The conditions of learning and theory of instruction* (Lambuth Campus Library - 2nd Level Stacks LB1051; 4th ed.). Holt, Rinehart and


interaction in a virtual high school. *Distance Education, 34*, 64–83.

https://doi.org/10.1080/01587919.2013.770430

Herman. (2012). *Institutional support for online course design and delivery: Faculty professional development incentives and programs* [Doctoral dissertation, State University of New York at Buffalo].

https://www.proquest.com/docview/1029860318/abstract/39BA6C477354C84PQ/1


https://doi.org/10.1007/s10755-012-9248-6


https://doi.org/10.1080/00461520701263368


https://doi.org/10.1142/9789811228001_0204


https://doi.org/10.1080/15391523.2007.10782493


Merrill, M. D. (2020). *First principles of instruction, revised edition*. AECT.


https://books.google.com/books?id=2QbADwAAQBAJ
https://doi.org/10.28945/4182

https://doi.org/10.1207/S1532690XCI1802_03


https://repository.up.ac.za/handle/2263/26924


https://doi.org/10.1007/978-3-319-66327-2_5


https://qualitymatters.org/sites/default/files/PDFs/StandardsfromtheQMHigherEducationRubric.pdf


https://doi.org/10.1007/s11423-019-09673-4


https://doi.org/10.1177/1932202X14533799


Shachar, M., & Neumann, Y. (2010). Twenty years of research on the academic performance differences between traditional and distance learning: Summative


Appendix A

Course Scan Instrument

**Scoring System**

*For Likert-scale items:*

None (0)

To some extent (1)  There are serious omissions or problems; the principle is reflected in fewer than 50% of items (eg activities or objectives) being evaluated

To large extent (2)  Generally OK, but there are some omissions or problems; the principle is reflected in between 51% and 80% of items being evaluated

To very large extent (3) Excellent; the principle is reflected in between 81% and 100% of items being evaluated

Not applicable (N/A) (88)

No information (N/I) (99)

*For binary items:*

Yes (1)

No (0)

SECTION 1. COURSE DETAILS

1.1. Random Course Identifier:

1.2. Coder Identifier:

1.3. LMS URL:
1.4. Date of analysis:

SECTION 2. OBJECTIVES AND ORGANISATION

2.1. Does the course specify the learner population that will engage in the course?
   Yes ☐ | No ☐

2.2. Does the course specify the change that needs to be promoted in the skill set of the learner population?
   Yes ☐ | No ☐

2.3. To what extent are the course objectives measurable?
   None ☐ | To some extent ☐ | To large extent ☐ | To very large extent ☐ | N/A ☐ | N/I ☐

2.4. To what extent are the course materials well organised?
   None ☐ | To some extent ☐ | To large extent ☐ | To very large extent ☐ | N/A ☐ | N/I ☐

2.5. Are the course requirements clearly outlined?
   Yes ☐ | No ☐

2.6. Is the course description clear?
   Yes ☐ | No ☐

SECTION 3. FIRST PRINCIPLES
3.1 To what extent are the course objectives relevant to real-world problems?
None □ | To some extent □ | To large extent □ | To very large extent □ | N/A □ | N/I □

3.2 To what extent are the problems in the course typical of those learners will encounter in the real world?
None □ | To some extent □ | To large extent □ | To very large extent □ | N/A □ | N/I □

3.3 To what extent do the activities in the course relate to the participants’ real workplace problems?
None □ | To some extent □ | To large extent □ | To very large extent □ | N/A □ | N/I □

3.4 To what extent are the problems ill-structured – ie have more than one correct solution?
None □ | To some extent □ | To large extent □ | To very large extent □ | N/A □ | N/I □

3.5 To what extent are the problems divergent from one another?
None □ | To some extent □ | To large extent □ | To very large extent □ | N/A □ | N/I □

3.6 Are there examples of problem solutions?
Yes □ | No □ | N/A □
3.7 If there are examples of solutions, to what extent do these solutions represent a range of quality from excellent examples to poor examples?

<table>
<thead>
<tr>
<th>None</th>
<th>To some extent</th>
<th>To large extent</th>
<th>To very large extent</th>
<th>N/A</th>
<th>N/I</th>
</tr>
</thead>
</table>

3.8 To what extent are the resources reused from real-world settings?

<table>
<thead>
<tr>
<th>None</th>
<th>To some extent</th>
<th>To large extent</th>
<th>To very large extent</th>
<th>N/A</th>
<th>N/I</th>
</tr>
</thead>
</table>

3.9 To what extent do the activities build upon each other?

<table>
<thead>
<tr>
<th>None</th>
<th>To some extent</th>
<th>To large extent</th>
<th>To very large extent</th>
<th>N/A</th>
<th>N/I</th>
</tr>
</thead>
</table>

3.10 To what extent do the activities attempt to activate learners’ relevant prior knowledge or experience?

<table>
<thead>
<tr>
<th>None</th>
<th>To some extent</th>
<th>To large extent</th>
<th>To very large extent</th>
<th>N/A</th>
<th>N/I</th>
</tr>
</thead>
</table>

3.11 To what extent do the activities require learners to apply their newly acquired knowledge or skill?

<table>
<thead>
<tr>
<th>None</th>
<th>To some extent</th>
<th>To large extent</th>
<th>To very large extent</th>
<th>N/A</th>
<th>N/I</th>
</tr>
</thead>
</table>

3.12 To what extent do the activities require learners to integrate the new knowledge or skill into their everyday work?

<table>
<thead>
<tr>
<th>None</th>
<th>To some extent</th>
<th>To large extent</th>
<th>To very large extent</th>
<th>N/A</th>
<th>N/I</th>
</tr>
</thead>
</table>

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3.13 To what extent are there activity options for participants with various learning needs?
None □ | To some extent □ | To large extent □ | To very large extent □ | N/A □ | N/I □

3.14 To what extent do the activities require participants to learn from each other?
None □ | To some extent □ | To large extent □ | To very large extent □ | N/A □ | N/I □

3.15 To what extent do the activities require participants to contribute to the collective knowledge, rather than merely consume knowledge
None □ | To some extent □ | To large extent □ | To very large extent □ | N/A □ | N/I □

3.16 To what extent do the activities require learners to build on other participants’ submissions?
None □ | To some extent □ | To large extent □ | To very large extent □ | N/A □ | N/I □

3.17 To what extent do the activities require participants to collaborate with other course participants?
None □ | To some extent □ | To large extent □ | To very large extent □ | N/A □ | N/I □

3.18 To what extent do the activities require participants to collaborate with others outside the course?
None □ | To some extent □ | To large extent □ | To very large extent □ | N/A □ | N/I □
3.19 To what extent do the activities require that the peer-interaction groups be comprised of individuals with different backgrounds, opinions, and skills?
None □ | To some extent □ | To large extent □ | To very large extent □ | N/A □ | N/I □

3.20 To what extent can the individual contribution of each learner in the group be clearly identified?
None □ | To some extent □ | To large extent □ | To very large extent □ | N/A □ | N/I □

3.21. Is there feedback opportunities on activities by the instructor(s) in this course?
Yes □ | No □

3.22. If there are feedback opportunities, is the way feedback will be provided clearly explained to the participants?
Yes □ | No □ | N/A □

3.23. Are the peer-interaction groups given specific directions for interaction?
Yes □ | No □ | N/A □

3.24. Does each member of a peer-interaction group have a specific role to play?
Yes □ | No □ | N/A □
### Appendix B

Descriptive statistics for individual Course Scan items

<table>
<thead>
<tr>
<th>Course Scan Question</th>
<th>M</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
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