

Integrating Theory and Structured Inquiry in Computer Science Ph.D. Research

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Theories serve as a necessary lens for facilitating a structured and informed assessment of research applications. Computer science often undergoes what may seem like sudden advancements, such as the rapid evolution of commercial artificial intelligence. Importantly, these developments arise from extensive, theory-based research conducted by scholars, including those at the doctoral level. Theories do not emerge from thin air or a magician's hat. Instead, they develop through investigation based on well-considered problem statements, purpose statements, and research questions. Theory is crucial because it comprises a recognized set of rules that should be implemented reasonably and logically. In the context of computer science at the doctoral level, theory directs investigation and broadens the discipline by continuously providing proven frameworks that enable necessary and structured inquiry; theory and inquiry are iterative, and as the field expands, established theories are utilized to advance the discipline. This iterative process ensures that research is constantly refined and updated, resulting in robust and reliable outcomes.

Research Statements and Questions

Problem Statement

Meaningful doctoral-level research begins with a problem statement, a crucial step that sets the stage for the entire research process. A problem statement must be specific, evidence-based, and a real-world issue (National University, n.d.). A well-constructed problem statement not only identifies gap(s) or inconsistencies in knowledge or practice but also underscores the consequences of leaving the issue unaddressed. It effectively highlights the difference between what is known and what should be understood or resolved. In computer science, a problem statement could involve identifying inefficiencies in applications of database designs or gaps in

cybersecurity protocols and what the consequences may be if these issues go unaddressed or are never researched.

Purpose Statement

The problem statement explains why the research is necessary but is not entirely focused on the ‘what’ or the ‘how’ matter. The purpose statement clarifies what will be done to address a problem and how the research is conducted (National University, n.d.); the purpose statement, usually qualitative or quantitative, summarizes the research design or methodology used to explore the problem identified. This might involve applying a theoretical framework or model to conduct an experimental study on algorithm performance or a case study on data storage practices in various computing environments. These studies are described in qualitative or quantitative purpose statements, depending on the desired outcomes when asking research questions.

Research Questions

A research question or its definition is relatively self-explanatory. However, a worthy research question is “clear, focused, concise, complex, and arguable” for a specific field (National University, n.d.). In computer science, such a question complements the problem and purpose statements by precisely guiding inquiry. For example, instead of asking, “What is an efficient database system?” which is overly broad, even if it appears to address certain key aspects, a more refined version might be, “Which database systems best complement the use of agentic AI by support staff in higher education?” which is clear, focuses on a particular problem and purpose, balances conciseness and complexity, and remains open to different interpretations or arguments.

Theoretical Framework in Computer Science

National University defines a theoretical framework as the “lens by which a study is developed” (Grant & Osanloo, 2014, as cited in National University, n.d.). In other words, it provides the conceptual (in nature, not framework) structure that shapes the direction and scope of a research study. The theoretical framework guides how the problem is examined, data is interpreted, and conclusions are drawn. Rather than simply presenting existing theories, the framework connects theories to a list of specific study objectives the researcher defines to form a basis for methodological decisions and research questions.

For computer science, theory can often feel abstract, not to be confused with the concept of abstraction, or disconnected from real-world relevance. Maurer (2021) observed that theoretical computer science may be perceived as presenting “theory for theory’s sake,” which can frustrate students seeking practical skills in their “Foundations of Computer Science” course. Nevertheless, theoretical computer science remains essential. At Baylor, Maurer redesigns the course to emphasize the practical use of theoretical concepts, specifically for concepts like finite state machines and push-down automata, as valuable tools that expand the problem-solving ability of modern computer scientists. This is important for understanding the role of a theoretical framework in computer science, which in this case is used as a tool for structured, relevant, and impactful research and practice.

What value does a theoretical framework hold for a doctoral-level computer science student? Every doctoral student anticipates writing a dissertation, including my future self. Without a theoretical framework, students lack a critical tool for developing research that meaningfully connects prior theory to new problems. This connection allows researchers to

bridge gaps, set work in established thought, and contribute meaningful and lasting advancements to the field.

Relevant Theories to Computer Science

Human-computer interaction is one of the field's most enduring and critical areas, focusing on the interconnection between humans and computers. More than ever, modern applications prioritize intuitive and efficient interaction, and theoretical frameworks are essential in connecting human cognition to technology or computer design. For example, Information Processing Theory, which examines how users receive, process, and retain information, offers value in guidance for designing interfaces that align with cognitive capabilities (Kretchmar, 2021). Similarly, the Technology Acceptance Model and Cognitive Load Theory embrace human-computer interaction by highlighting the psychological and perceptual parameters influencing system usability, human engagement, and adoption.

Information Processing Theory

In the article *Deployment of Information Processing Theory to Support Adaptive E-Learning Systems: Feasibility Study*, Mwambe (2024) explores how Information Processing Theory serves as a theoretical lens for understanding how users, specifically students, perceive, process, and retain digital content. The study illustrates how the Information Processing Theory can inform the development of adaptive e-learning systems by aligning design features with cognitive preferences such as attention, interactivity, and cognitive load. In this study, Mwambe demonstrates that tailoring multimedia content to “Generation Z” learners improves the learning outcomes among ~100 participants. Constructs such as short-term and long-term memory, bioinformatics, and engagement are key in the design of the ‘DIT-eLMS’ platform. This

research underscores the value of the Information Processing Theory in human-computer interaction as it effectively connects theoretical insight with system development.

Technology Acceptance Model

In their study, *Technology Acceptance Model in Government Context*, Amali et al. (2022) demonstrate how the Technology Acceptance Model can guide research on adopting information systems in government institutions. The study focuses on IT governance, analyzing how perceived usefulness, perceived ease of use, and behavioral intention influence the actual usage of digital computing systems. Though the context is rooted in information systems and public administration, the theoretical framework is directly relevant to computer science, particularly in human-computer interaction, understanding where human behavior and interaction is critical. The Technology Acceptance Model framework utilized in this study offers insight into where users accept or reject digital systems to design and evaluate usable and practical technology with existing hypotheses between states such as “Perceived Ease of Use (PEOU)” and “Attitude Toward Using Technology (ATUT)” (Amali et al., 2022).

Cognitive Load Theory

Cognitive Load Theory is notably relevant to computer science education due to the cognitive demands of learning computer programming. Berssanette and de Francisco (2022), in their literature review, *Cognitive Load Theory in the Context of Teaching and Learning Computer Programming*, examine how Cognitive Load Theory is applied to improve instructional design in programming education. The findings from this review highlight key concepts of the theoretical framework, including underlying and extraneous cognitive load, memory limits both short and long-term, and schema construction, as essential to understanding how learners process complex programming tasks. The study highlighted the effectiveness of

such with worked examples and subgoal labeling to reduce learner overload and improve learning outcomes. Cognitive Load Theory provides an efficient theoretical framework that is informative for educational methodology and system design, reinforcing the value of human-computer interaction research in computer science.

Peer-Reviewed Articles

Information Processing (Learning) Theory

Information Processing Learning Theory is an instructional adaptation of the previously mentioned Information Processing Theory. It is a practical abstraction of this theory, reflecting how abstraction operates in computer science. In their study, Moon et al. (2025) applied this theory to develop a learning model for visual-to-auditory sensory substitution, a technology designed to assist visually impaired users in interpreting visual information through auditory signals. Participants in the study exhibited improvement in short-term learning compared to those engaged in randomized repetition learning. This illustrates that theory-based learning, a derivative of the significant Information Processing Theory in computer science, has a meaningful impact on human-computer interaction from a theoretical perspective.

Technology Acceptance Model

The study by Adouani and Khenissi (2024) extends the Technology Acceptance Model to evaluate computer science students' intentions to use an online education platform in Tunisia. This extended model builds on the original Technology Acceptance Model developed by Davis (1986), incorporating constructs such as Social Norm, Perceived Enjoyment, Perceived System Quality, and Perceived Interaction to more fully explain student behavior in modern (online) learning environments. The research found that these additional variables improved the model's predictive power. The Extended Technology Acceptance Model maintains the foundational

structure of the original Technology Acceptance Model while enhancing its applicability to more complex, real-world contexts.

Cognitive Load Theory

Data structures are a core concept of computer science education, but they present significant cognitive challenges for students due to their algorithmic/abstract nature. Arévalo-Mercado et al. (2023) applied Cognitive Load Theory in the design and testing of a tool that aimed at reducing cognitive overload when learning about linked lists, a “simple” data structure. The tool was based on the Split Attention Effect, a principle of Cognitive Load Theory that makes the learners' experience an unnecessary cognitive burden when information is presented in jumbled formats. By utilizing node diagrams and example code within an interface, the researchers helped students form stronger mental schemas and reduce cognitive load. The experimental group showed statistically significant improvements ($p = 0.000$) in test scores compared to the control group. This study showed how Cognitive Load Theory can inform instructional design in a computer science education, reinforcing the practicality in human-computer interaction contexts.

Conclusion

Theories serve as a crucial backbone for doctoral-level research in computer science, providing frameworks to explore complex problems. In a field where technological evolution seems to outpace reflection, theoretical frameworks enable researchers to ground innovation in established principles. This is exemplified by the Information Processing Theory, the Technology Acceptance Model, and the Cognitive Load Theory, which connect inquiry to application. Whether guiding the design of learning systems, evaluating user adaptation, or shaping education as seen in Maurer or Arévalo-Mercado's examples, theory ensures that

research is methodologically sound and impactful. For doctoral researchers, the ability to align inquiry with theory and its frameworks is essential for contributing meaningful knowledge to the field.

References

- Berssanette, J. H., & de Francisco, A. C. (2022). Cognitive Load Theory in the Context of Teaching and Learning Computer Programming: A Systematic Literature Review. *IEEE Transactions on Education, Education, IEEE Transactions on, IEEE Trans. Educ*, 65(3), 440–449. <https://doi.org/10.1109/TE.2021.3127215>
- Deok Moon, K., Kyung Park, Y., Seop Kim, M., & Jeong, C. Y. (2025). Improving Acceptance to Sensory Substitution: A Study on the V2A-SS Learning Model Based on Information Processing Learning Theory. *IEEE Transactions on Neural Systems and Rehabilitation Engineering, Neural Systems and Rehabilitation Engineering, IEEE Transactions on, IEEE Trans. Neural Syst. Rehabil. Eng*, 33, 1097–1107. <https://doi.org/10.1109/TNSRE.2025.3548942>
- Grant, C., & Osanloo, A. (2014). Understanding, Selecting, and Integrating a Theoretical Framework in Dissertation Research: Creating the Blueprint for Your “House.” *Administrative Issues Journal: Connecting Education, Practice, and Research*, 4(2), 12–26.
- Kretchmar, J. (2021). *Cognitive Neuroscience*. Salem Press Encyclopedia.
- Lanto Ningrayati Amali, Muhammad Rifai Katili, Sitti Suhada, Lillyan Hadjaratie, & Hanifah Mardlatillah. (2022). Technology Acceptance Model in Government Context: A Systematic Review on Implementing IT Governance in a Government Institution. *JOIN: Jurnal Online Informatika*, 7(1), 80–88. <https://doi.org/10.15575/join.v7i1.853>
- Maurer, P. M. (2021). *Computer Science Theory from a Practical Point of View*. 2021 International Conference on Computational Science and Computational Intelligence

(CSCI), Computational Science and Computational Intelligence (CSCI), 2021 International Conference on, CSCI, 920–924.

<https://doi.org/10.1109/CSCI54926.2021.00209>

National University. (n.d.). Problem statement overview. NU Library.

<https://resources.nu.edu/c.php?g=1006886&p=7294692>

National University. (n.d.). Purpose statement overview. NU Library.

<https://resources.nu.edu/c.php?g=1006886&p=7294752>

National University. (n.d.). Quantitative research questions. NU Library.

<https://resources.nu.edu/c.php?g=1109615&p=9209099>

National University. (n.d.). Theoretical framework. NU Library.

<https://resources.nu.edu/c.php?g=1006886&p=9620737>

Othmar Othmar Mwambe. (2024). Deployment of information processing theory to support adaptive e-learning systems: Feasibility study. Computers in Human Behavior Reports, 14(100420-). <https://doi.org/10.1016/j.chbr.2024.100420>

Yassine Adouani, & Mohamed Ali Khenissi. (2024). Investigating Computer Science Students' Intentions towards the Use of an Online Educational Platform Using an Extended Technology Acceptance Model (e-TAM): An Empirical Study at a Public University in Tunisia. *Education and Information Technologies*, 29(12), 14621–14645.

<https://doi.org/10.1007/s10639-023-12437-6>