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Analytical Examination of Fuzzy Logic's Impact on Instructional Design from Expert Viewpoints and Proposed Solutions

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ABSTRACT:
This research, which follows a descriptive-analytical approach using survey-based investigation, explores the role of Fuzzy logic within instructional design through the perspectives of experts and proposes solutions. The study encompasses faculty members, graduates, and students pursuing master's and doctoral degrees in educational technology at state universities in Tehran. The research utilized convenience sampling, with a sample size of 97 individuals. Data was collected using a researcher-developed questionnaire based on the Likert scale, which underwent validation through content validity and exhibited a high level of reliability with a Cronbach's alpha coefficient of 95%. The findings indicate that the obtained results for the teaching-learning process are statistically significant at a significance level of $P \leq 0.01$, suggesting that the integration of Fuzzy logic-based instructional design can enhance the effectiveness of learning and teaching. Similarly, the obtained results for instructional quality reveal statistical significance at a level of $P \leq 0.01$, indicating that the adoption of Fuzzy logic-based instructional design can lead to improvements in the quality of education. Additionally, the obtained results for instructional evaluation demonstrate statistical significance at a level of $P \leq 0.01$, implying that the utilization of Fuzzy logic-based instructional design can yield effective evaluation outcomes.

Keywords: Fuzzy Logic, Instructional Design, Educational Quality, Learning-Teaching Process

INTRODUCTION:

Instructional design, a relatively nascent yet continuously developing field, aims to optimize the efforts of educators and trainers through the application of scientific and practical principles (Norouzi and Razavi, 2015). This discipline focuses on formulating or forecasting the most effective educational strategies to facilitate desired transformations in learners' knowledge, abilities, and emotional states. Instructional designers employ various design models to forecast the most suitable methods for learning and teaching that target improvements in cognitive, affective, and psychomotor dimensions. Viewing educational activities as an intergenerational investment underscores their primary objective: human development. Essentially, the purpose of these activities is to enhance human consciousness and unlock potential capabilities (Beiramipur, 2009). Furthermore, the educational sector in each nation accounts for the highest proportion of human resources and job creation compared to other governmental sectors. Consequently, the educational system is recognized as one of the most intricate subsystems within the broader social, economic, and cultural frameworks (Jafarnejad, 2016).

If instructional design is executed using binary logic, it fails to consider the specific learning needs and capabilities of learners. As a result, the creation and production of educational media do not align with these requirements, and ultimately, an accurate evaluation of educational effectiveness is unattainable. With the rapid progress in various scientific fields and the introduction of new theories, methods, and tools—particularly with the introduction of multi-valued fuzzy logic in the mid-twentieth century and the subsequent acceleration of technological advancements, along with the development of intelligent systems through the use of Fuzzy logic—the importance of investigating the use of this logic in a key sector of the Educational Technology field, specifically in instructional design, has become clear.

Fuzzy logic has been widely applied to evaluate qualitative issues and patterns, significantly addressing numerous challenges within the educational sciences, which also inspired this research due to the subject's innovative nature. While there have been investigations into the use of Fuzzy logic, these are predominantly in basic and technical sciences, with only a few exceptions (Ayat and Horri Najafabadi, 2010; Gharabaghi, 2009; Haddadinejad, 2005) addressing educational sciences. Previous studies have focused on aspects like teacher performance evaluation and the quality of curricula, yet instructional design remains largely unexamined. Given the impact of instructional design on educational quality, this research has included it as a key parameter. By exploring the insights of experts, particularly in

education, this study aims to provide a more detailed analysis of Fuzzy logic's role in instructional design. Furthermore, consulting the opinions of educational experts will enhance understanding of the strengths and weaknesses of this approach.
The implementation of Fuzzy logic in instructional design is crucial due to the value and prominence of education within society. When education is highly valued, it becomes imperative to furnish it with sophisticated and modern tools. In contrast to binary logic, which is limited to two values and lacks initial definitive decision-making, Fuzzy logic, with its multi-valued approach, evaluates various conditions (if-then scenarios) and makes decisions after considering multiple outcomes, thus enhancing accuracy and retaining information.
Historically, educational discussions often focused on binary labels such as smart, lazy, good, and bad. Today, the perspective has shifted. It is now recognized that a student might excel in one subject but struggle in another; therefore, absolute categorizations do not apply. Rather than assessing students as a homogeneous group, each student should be evaluated on an individual basis. Instead of broadly labeling students as good, smart, or lazy, it is more appropriate to quantify the degree to which these characteristics apply, such as how good, how smart, or how lazy a student may be (Saroukhani and Sadeghipour, 2013).
If instructional design is conducted using multi-valued logic, it ensures that the needs and abilities of learners are effectively addressed with high accuracy and without any loss of information. As a result, the development and production of educational media are tailored to meet these specific needs, allowing for an accurate assessment of educational outcomes. Utilizing Fuzzy logic enables the representation of problem parameters as fuzzy numbers rather than confining them to a single value. Given that both the lower and upper limits of responses are accessible, it becomes feasible to investigate the use of Fuzzy logic in instructional design. This approach involves devising detailed strategies for achieving educational objectives. As instructional designers frequently encounter uncertainties, and traditional probability theory and binary logic often fall short of providing effective solutions, the application of Fuzzy logic can effectively mitigate these uncertainties and aid instructional designers in their work.

Theoretical Foundations:

Instructional Design:

Instructional design methodically develops educational standards using theories of learning and teaching to guarantee the quality of education. It involves a detailed process of identifying learning needs and goals and constructing a functional system to address these requirements. Additionally, it includes the creation of educational materials and activities, the execution of pilot programs, and the assessment of all educational initiatives and learner participation.
The process of instructional design can be initiated at any stage of the design cycle. Often, a brainstorming session catalyzes the creation of an educational scenario. In a thorough process, the designer reviews all the knowledge segments that need to be conveyed (Khademi, 2013). Instructional design is concerned with comprehending, enhancing, and implementing instructional strategies to achieve learning that is effective, efficient, and engaging (Reigeluth and Stein, 1983). Viewing educational sciences broadly to encompass five areas—teaching, curriculum, counseling, management, and evaluation—instructional design is recognized as a component of teaching. This component is involved in the production of educational content, the execution of educational initiatives, the administration of educational programs, and the evaluation of these programs.
In instructional design, the designer concentrates exclusively on teaching methodologies and defers decisions about the content to be taught to curriculum planners, suggesting that curriculum planning and instructional design operate in parallel, not perpendicularly (Leshin, Pollock, and Reigeluth; translated by Fardanesh, 2010). At the micro-level, instructional designers focus on specifics such as crafting definitions, examples, and questions, and they plan the number of examples, exercises, and presentation methods. Micro-level models are concerned with the details of educational activities and specific teaching methods for educational content, closely mirroring the tasks that teachers carry out in classrooms (Fardanesh, 2008). At the macro level, instructional design involves outlining the complete structure and development of the entire educational process from beginning to end. Models at this level deal with the overarching organization of educational activities and the general design of programs, courses, or lessons. This aspect of instructional design is highly akin to the work performed by curriculum planners (Fardanesh, 2008).

Constructivism and Instructional Design:

Constructivism presents a marked departure from conventional knowledge acquisition methods. It counters objectivist and positivist epistemological stances. In contrast to positivist views, advocates of constructivism, rooted in relativism, contend that knowledge is not an external entity to be uncovered but is instead personally formulated based on individual learner experiences.
Under the constructivist framework, learners actively construct knowledge rather than passively absorbing it from external sources. This philosophy places a strong emphasis on the active creation and interpretation of knowledge, highlighting its dynamic, relative, internal, transformative, and social nature, and its dependency on cultural and specific contextual factors.
Constructivism advocates for a learning philosophy where knowledge is built either individually or collectively. Essentially, students develop their understanding based on pre-existing schemas or

beliefs. Constructivists reject the notion of an independent body of knowledge, separate from the meanings learners or communities of learners ascribe to their experiences (Hein, 1999).

Constructivism posits that learners actively construct knowledge by striving to make sense of their experiences. They interpret new data and connect it to frameworks developed from prior experiences. The acquisition of knowledge necessitates learners' active interpretation to forge new links within existing frameworks. This dynamic is crucial for learning, problem-solving, reasoning, critical thinking, and the innovative application of knowledge.

From a constructivist standpoint, learning is a result of mental construction, occurring when new information is synthesized in the mind or when new perceptions and mental skills augment the existing knowledge structure. Consequently, optimal learning occurs when individuals actively construct their knowledge and perceptions (Pritchard, 2009). The epistemological underpinnings of constructivism have precipitated significant shifts in the foundational discussions across various educational disciplines, particularly in educational technology and, by extension, instructional design. According to Reigeluth, the transition from industrial-era educational methodologies to those of the information age entails moving from the creation of standardized educational programs to designing tailored programs for individual learners. In this contemporary stage, designers are tasked with crafting distinct learning experiences for each student rather than generating uniform, predetermined learning outcomes for all. This shift is facilitated by rapid advancements in communication and computer technologies (Fardanesh, 2008).

Fuzzy System:

Fuzzy systems are increasingly utilized in a diverse array of scientific and technological fields, ranging from control systems, signal processing, and communications to the creation of integrated circuits, as well as in expert systems, business, medicine, and the social sciences. Among their most significant uses is in addressing control issues. These systems can function as either open-loop or closed-loop controllers. As open-loop controllers, fuzzy systems generally establish specific control parameters, which the system then follows in its operation. This application is particularly prevalent in the field of electronics (Borg, 1993).

Fuzzy systems operate based on knowledge or predefined rules. At the heart of a fuzzy system lies a knowledge base made up of fuzzy if-then rules. These rules are conditional statements in which certain terms are defined by ongoing membership functions. For instance, take the fuzzy statement: "If the car's speed is high, then apply less force to the gas pedal," where the terms 'high' and 'less' are quantified by membership functions depicted in diagrams. Essentially, a fuzzy system is built upon a collection of such fuzzy if-then rules (Strategic Studies and Research Center, 2014).

Research Background:

In their 2016 research titled "A Novel Method in Evaluation and Ranking of Teachers," Jafarnejad, Zeinabadi, and Ayedi Koushki discussed that the development of a high-quality education system reliant on proficient teachers cannot occur without recognizing their strengths and weaknesses, providing ongoing professional development, and offering continuous training that adapts to advancements in information technology. They emphasized that a key approach in many countries for achieving these objectives is the regular assessment of teachers. The findings from their study suggest that the developed software model outperforms traditional methods due to its operation within a software environment, its application of qualitative criteria, its integration of artificial intelligence techniques (with a 93% effectiveness), and its significantly enhanced flexibility for conducting automated operations, as well as improved speed, precision in ranking, and evaluation of employee performance.

In a 2016 study titled "Design of Educational Systems and Educational Technology," Rastegarpour claimed that the expert system used in the research served as a proficient career advisor, possessing comprehensive knowledge about the attributes and details of various professions.

Mazaheri and Ghanbari, in their 2015 research "Application of Fuzzy Systems in Educational Measurements," noted that the traditional approach in the assessment of educational progress involves the collection and utilization of test scores.

In his 2009 study, "Critique of the Epistemology of Connectivism (Communicative Knowledge and Distributed Knowledge) Based on Islamic Epistemology," Eskandari highlighted the crucial role of expert systems in addressing key shortcomings of electronic learning systems. He noted that these systems boost the effectiveness of e-learning by fostering an intelligent dialogic environment. Furthermore, expert systems can surmount the "one size fits all" approach in education, facilitating the development of tailored, adaptive learning systems.

Khan, in his 2011 research "Assessing the Quality of Instructors in Higher Education Institutions" and employing fuzzy logic, emphasized that the evaluation of teaching quality is among the most effective universal methods for pinpointing the educational system's strengths and weaknesses. Within the Croatian higher education context, the Ministry of Higher Education administers the quality assessment process, which includes evaluating the pedagogical quality of the faculty.

In their 2013 article, "A Fuzzy Web Methodology Based on Fuzzy Logic for Assessing Websites," Rekik and Kallehi detailed a new methodology for qualitative assessment and a service evaluation model known as "fuzzy web." This model leverages fuzzy logic to evaluate the quality of websites effectively.

In his 2013 paper titled "The Application of Fuzzy Logic in Assessing the Effectiveness of Systems," Voskoglou introduced a broad fuzzy model that utilizes various representations of system performance, classified through indistinct propositions. Within this framework, he outlined three performance assessment systems based on fuzzy logic. These systems encompass a comprehensive model of uncertain probabilistic systems, a positive Shannon entropy system suitable for fuzzy settings, and a central approach for adjusting membership function graphs.

Instructional design focuses on the components that constitute an educational program, involving the manipulation of various elements and the execution of specific tasks. Within this framework, the instructional design model plays a crucial role in shaping both the elements and the processes involved (Norouzi and Razavi, 2016). This entails designing events or activities essential for facilitating learning. The instructional design process encompasses a sequence of interlinked and mutually dependent steps. This includes conducting learner analysis, context analysis, goal analysis, setting educational objectives, choosing strategies and assessment tools, creating educational materials, and assessing learner performance (Chen, 2008).

Instructional design is heavily dependent on data, necessitating that instructional designers diligently seek the most valid and precise information through scientific methods. It operates within the context of real-world considerations and involves a series of decision-making and selections. The process of instructional design demands a systematic and explicit approach (Norouzi and Razavi, 2016). Similarly, fuzzy logic, akin to instructional design, requires progressing through stages and undertaking specified actions. Like instructional design, fuzzy logic examines components, particularly how instructional design evaluates the context of knowledge, skills, and capabilities. Contextualism is a fundamental intellectual foundation of this approach; it advocates for a holistic view—seeing the forest rather than just a single tree—and thus, eschews any form of abstraction (Saroukhani and Sadeghipour, 2017).

Fuzzy logic engages with real-world scenarios and requires a series of decisions and selections. Similar to how an instructional designer functions in uncertain conditions, fuzzy logic is adept at handling uncertainty, thereby minimizing errors. Consequently, fuzzy logic is employed not only in the field of education but across various industries today.

RESEARCH METHOD:

The approach employed in this study is descriptive-analytical, focused on defining and formulating criteria that clarify the role of fuzzy logic in Instructional Design. The research utilizes a mixed-methods approach, integrating both analytical and survey-based field studies. The demographic for this study comprises faculty members, graduates, and both master's and doctoral students specializing in Educational Technology at public universities in Tehran. Doctoral studies are offered at Allameh Tabataba'i University and Tarbiat Modares University, while master's programs are available at Allameh Tabataba'i and Kharazmi Universities in Tehran. Convenience sampling was utilized for this research, with data collection facilitated through a researcher-created questionnaire containing 25 questions aimed at evaluating and measuring the study's variables.

To ensure content validity, the research sought insights from supervising professors, advisors, and Educational Technology experts, who also validated the questionnaires. The reliability of the questionnaire was established using Cronbach's alpha method, which confirmed a reliability rate of 95%.

For inferential data analysis, statistical tests such as the chi-square test and one-way ANOVA were employed, with the data subsequently analyzed using SPSS software.

Research Questions:

Primary Research Question

Is there a role for Fuzzy logic in enhancing the efficiency of Instructional Design?

Subsidiary Research Questions

1. Is Instructional Design that incorporates Fuzzy logic effective in facilitating learning and teaching?
2. Can Instructional Design that utilizes Fuzzy logic effectively contribute to problem-solving?
3. Is it possible to effectively use Instructional Design based on Fuzzy logic in evaluations?

FINDINGS:

The findings show that 6.52 percent of the participants were female and 4.47 percent were male. The age breakdown of the participants is as follows: 4.45 percent were aged between 25 and 30 years, 4.14 percent between 31 and 35 years, 6.18 percent between 36 and 40 years, 3.10 percent between 41 and 45 years, 2.8 percent between 46 and 50 years, 1.2 percent between 51 and 55 years, and 1 percent were over 56 years old. Regarding educational qualifications, 8.60 percent of the participants held a master's degree, and 2.39 percent possessed a doctoral degree. Concerning job roles, 1.3 percent of the participants were senior managers, 2.8 percent were middle managers, 1.1 percent were deputies, 8.26 percent were employees, 2.8 percent were specialists, and 6.52 percent were categorized as others.

Table 1: Descriptive Statistics of Variables

Variables	Mean	Standard Deviation	Skewness	Kurtosis	Minimum Score	Maximum Score
Learning-Teaching Processes	34.62	5.68	-0.667	0.194	17	45
Problem-Solving	33.39	5.64	-0.458	-.0.369	19	45
Evaluation	26.53	4.69	-0.455	-0.216	14	36

For the Learning-Teaching Processes variable, the mean and standard deviation are recorded at 62.34 and 68.5, respectively. The minimum and maximum scores for this variable within the sample group are 17 and 45, respectively. In the case of the Problem-Solving variable, the mean is 39.33 and the standard deviation is 64.5, with the lowest and highest scores in the sample being 19 and 45, respectively. Lastly, for the Evaluation variable, the mean and standard deviation stands at 53.26 and 69.4, respectively, with the lowest score being 14 and the highest reaching 36 within the sample group.

Table 2: T-test on the Role of Fuzzy Logic in Instructional Design and Its Efficiency Enhancement

Group	Empirical Mean	Theoretical Mean	Mean Difference	Degrees of Freedom	t-value	Significance Level
Instructional Design	55.94	75	55.19	96	89.13	0.0001

The empirical mean recorded for Instructional Design is 55.94, which exceeds the theoretical mean by 55.19. This difference is statistically significant at the P≤0.01 level. Therefore, the obtained mean demonstrates a significant deviation from the theoretical mean. Consequently, Fuzzy logic plays a significant role in enhancing the efficiency of Instructional Design.

Table 3: T-test on the Implementation of Instructional Design Based on Fuzzy Logic in Learning and Teaching

Group	Empirical Mean	Theoretical Mean	Mean Difference	Degrees of Freedom	t-value	Significance Level
Learning-Teaching Processes	62.34	27	62.7	96	21.13	0.0001

The observed mean value in the teaching-learning processes stands at 62.34, exceeding the theoretical mean by 62.7. This difference is statistically significant at the P≤0.01 level. Thus, there is a meaningful discrepancy between the obtained mean and the theoretical mean. As a result, employing Instructional Design that utilizes Fuzzy Logic can significantly enhance the effectiveness of teaching and learning processes.

Table 4: T-test on the Impact of Using Instructional Design Based on Fuzzy Logic in Problem-Solving

Group	Empirical Mean	Theoretical Mean	Mean Difference	Degrees of Freedom	t-value	Significance Level
Problem-Solving	33.39	27	6.39	96	14.11	0.0001

The measured mean value in problem-solving stands at 33.39, surpassing the theoretical mean by 6.39. This outcome is statistically significant at the level of P≤0.01. Thus, there is a significant variation between the observed mean and the theoretical mean. As a result, employing Instructional Design that incorporates Fuzzy Logic can significantly enhance problem-solving effectiveness.

Table 5: T-test on the Impact of Using Instructional Design Based on Fuzzy Logic in Evaluation

Group	Empirical Mean	Theoretical Mean	Mean Difference	Degrees of Freedom	t-value	Significance Level
Evaluation	26.53	21	5.53	96	61.11	0.0001

The observed mean value in evaluation measures 26.53, exceeding the theoretical mean by 5.53. This difference is statistically significant at the level of P≤0.01. Hence, there is a significant discrepancy between the observed mean and the theoretical mean. As a result, instructional design utilizing fuzzy logic can significantly influence evaluation processes.

DISCUSSION:

The findings demonstrate that the empirical mean value recorded in Instructional Design is 94.55, which exceeds the theoretical mean by 19.55. This discrepancy is statistically significant at the level of P≤0.01. As a result, there is a significant difference between the obtained mean and the theoretical mean, underscoring the role of Fuzzy Logic in improving the efficacy of Instructional Design. These results are consistent with the studies conducted by Mazaheri and Ghanbari (2015), Darzi and colleagues (2010), Haddadinejad (2005) within the country, and Rekik and Kallehi (2013) internationally.

The cited research has tackled the educational system's challenges in needs assessment and educational program planning, particularly focusing on the selection of suitable training and skill courses using a Fuzzy Logic approach. These studies report that in this research, educational courses are delivered using an example-based reasoning method and Fuzzy Logic. According to these findings, Fuzzy Logic significantly improves the efficiency and effectiveness of Instructional Design and planning, thereby positively influencing Instructional Design.

The mean and standard deviation recorded in the teaching-learning processes are 34.62 and 5.68, respectively. In this variable within the sample group, the lowest score recorded is 17, and the highest is 45. The empirical mean value recorded in the teaching-learning processes is 34.62, which exceeds the theoretical mean by 7.62, and this difference is statistically significant at the level of $P \leq 0.01$. Thus, there is a significant deviation between the obtained mean and the theoretical mean. As a result, employing Instructional Design based on Fuzzy Logic can significantly influence teaching and learning.

This finding is consistent with the domestic studies of Kareshki, Pakmehr, and Mohammadzadeh Ghasr (2013), and with Smith's (2005) international research. This consistency stems from the beneficial effects of Fuzzy Logic on teaching and learning. Fuzzy Logic incorporates contextual considerations, and in the teaching-learning process, it accounts for the personal experiential contexts of learners. Considering that the teaching approach in the teaching-learning process should be adaptable and customized to fit the learners' needs and educational circumstances, Fuzzy Logic, with its capacity for multiple values, offers the necessary flexibility that enhances the depth of the teaching-learning process.

The data reveals that the mean and standard deviation for the problem-solving variable are 33.39 and 5.64, respectively. Within the sample group, scores ranged from a low of 19 to a high of 45. The empirical mean for problem-solving stands at 33.39, which exceeds the theoretical mean by 6.39. This discrepancy is statistically significant with a level of $P \leq 0.01$, indicating a meaningful difference from the theoretical mean. As a result, Instructional Design that incorporates Fuzzy Logic can significantly enhance problem-solving effectiveness.

This finding aligns with the domestic studies by Jafari and Azar (2013) and the international research by Voskoglou (2013). During the phase of solution generation, although no constraints are applied, each problem inherently possesses an optimal solution that should be selected from among the identified solutions for execution. Therefore, it's crucial to assess the available solutions for problem-solving. The most suitable solution is selected from the options available and then executed. Known for its if-then rules, Fuzzy Logic systematically evaluates different conditions and solutions, ultimately facilitating the best decision. It is evident that Fuzzy Logic positively influences the problem-solving process, promoting creativity and the exploration of diverse solutions.

CONCLUSION:

This study was undertaken to explore the impact of fuzzy logic on instructional design and its efficacy. Consequently, it is determined that employing fuzzy logic in instructional design results in more accurate and learner-specific designs. Additionally, it enhances the utilization of educational resources and equipment and ensures the necessary conditions for conducting educational activities are met. Ultimately, education becomes more efficient and fulfilling.

A limitation of this research is its reliance on a convenience sample and a questionnaire. Therefore, it is advised that the findings be generalized cautiously and with consideration of all factors. Based on these findings, it is recommended that universities advocate for the integration of fuzzy logic into educational sciences, particularly in instructional design and fields related to fuzzy structures.

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