



ORIGINAL RESEARCH ARTICLE

## Application of the Stirling-Darling Technique in an Intelligent Knowledge Extraction Model for Educational Environments

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### ABSTRACT

This study aims to present an intelligent knowledge extraction model for educational environments. The participants were managers of educational centers. Sampling was conducted with 18 experts and specialists. The data collection tools were a review of upstream documents related to education and data extraction in the library section, and semi-structured interviews. The content analysis method based on the Attride-Stirling model was employed to analyze qualitative data. To measure reliability, the Holst coefficient, Scott's p-coefficient, Cohen's kappa index, and Krippendorff's alpha were utilized and confirmed. ATLASTI software was utilized in the content analysis section. In the research employing the Stirling-Darling technique, 75 initial codes were identified across 15 initial themes, which were further categorized into 5 constituent themes. Foundational Concepts and Theoretical Frameworks, Technological Integration and Data Management, Learning Environments and Pedagogical Strategies, Assessment, Evaluation, and Challenges, Future Directions, Professional Development, and Community Engagement. The successful implementation of knowledge extraction in educational centers necessitates a comprehensive approach that considers all these elements in an integrated manner. Advanced technologies should be employed to collect and analyze educational data. Furthermore, the internal and external conditions of educational institutions should be designed and enhanced to facilitate the optimal utilization of this data. This initiative has the potential to transform educational processes and result in significant enhancements in the quality of teaching and learning within educational institutions. To facilitate the flourishing of knowledge extraction within educational models and enhance educational centers, it is crucial to pay attention to infrastructure, internal conditions, and environmental factors.

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## 1. Introduction

In today's world, new information and communication technologies have become deeply integrated into educational environments (Parriaux et al., 2023). One of the significant applications of these technologies is intelligent knowledge mining, which can enhance teaching and learning processes in educational institutions (Hassanzadeh, 2020).

Intelligent knowledge mining refers to the process of analyzing educational data through advanced techniques designed to uncover latent patterns, intricate relationships, and concealed information within the data (Nordsieck et al., 2021). In this context, artificial intelligence and machine learning systems play a crucial role, as they can simulate human cognitive processes and analyze vast amounts of data (AlMulhim, 2020). This process can significantly help identify student needs, enhance teaching methods, and assess educational performance (Allison et al., 2022). Despite its numerous benefits, educational institutions have not yet fully harnessed the potential of intelligent knowledge mining. In many schools and universities, data collected from students is analyzed in a fragmented and underutilized manner (Zielińska, 2016). Additionally, developing a profound and effective understanding of how this data can be utilized to enhance educational processes continues to pose a significant challenge (Zimpel-Leal & Lettice, 2021).

In many instances, information is not adequately analyzed, and existing algorithms for knowledge mining are not optimally designed to assist teachers and educational administrators in making informed decisions. This results in missed opportunities to enhance learning and teaching processes (Aramoon & Aramoon, 2019). In addition, one of the fundamental challenges in intelligent knowledge mining within educational environments is the absence of unified standards for data collection and analysis (Sedkaoui & Khelfaoui, 2021). Educational data is derived from a variety of sources, including assignments, tests, online interactions, classroom activities, and interviews, each possessing its own unique characteristics and structure (Segooa, Kalema, & Zolait, 2019). Without data standardization and unified methodologies, the analyses conducted may lack adequate accuracy and precision (Sghir et al., 2023).

Additionally, the complexities stemming from individual differences in student behavior and learning mean that the identified patterns cannot be universally and effectively applied in all contexts. This necessitates intelligent and customizable solutions that can continuously adapt to evolving educational needs (Waghmare, 2020).

It can be said that intelligent knowledge mining in educational environments can significantly affect the quality of education, but this requires attention to various aspects such as the design of artificial intelligence systems, training teachers in the use of these technologies, and the development of appropriate infrastructure (Butkus et al., 2022; Magoti & Mtui, 2020; Grubel & Walker, 2019).

In addition, issues such as the privacy and security of student data should also be considered to prevent possible misuse and abuse. Therefore, for the successful implementation of intelligent knowledge mining in educational environments, technical, ethical, and organizational issues must be addressed simultaneously so that this technology helps improve teaching and learning processes at all levels.

The Stirling-Darling technique is one of the advanced methods in data analysis that can be effectively used in intelligent knowledge mining models in educational environments (Ogata et al., 2024). This technique, using sophisticated probabilistic and mathematical methods, is able to discover hidden patterns and complex relationships that lie in educational data.

Due to the high complexity of educational data and their great diversity, the use of such methods can be effective in identifying relationships between different variables, such as student performance, teaching methods, and environmental conditions. As a result, the application of the Stirling-Darling technique can help teachers and educational

administrators to have more accurate analyses of educational trends and make better decisions to improve the teaching-learning process (Peng et al., 2023).

One of the main problems in educational environments is the large volume of data collected from various sources that are sporadically available. Here, the Stirling-Darling technique can serve as an efficient tool for analyzing this data.

This method, using probabilistic models, can simulate the fluctuations and complex features inherent in the data and explore the relationships between different data more precisely. For example, this technique can be used to predict and evaluate the impact of characteristics such as students' socio-economic status, different teaching methods, and individual characteristics such as motivation and interest in learning on educational performance. Another advantage of using the Stirling-Darling technique in intelligent knowledge mining models is its ability to simulate results based on different scenarios.

This feature allows educational designers to predict which approaches in specific situations can lead to improved student performance. Using this technique, simulations can be performed to assess the possible effects of changes in curricula, teaching methods, or even environmental conditions such as changes in the classroom environment. This information can help teachers and educational administrators make better decisions to optimize educational processes (Huang et al., 2024).

Applying the Stirling-Darling technique in intelligent knowledge extraction models can help improve the accuracy and quality of decision-making in educational environments. Given the ability of this method to analyze and process complex data, it can be used to identify students with special needs, predict learning problems, and improve the quality of teaching. Also, this method can effectively detect hidden educational issues such as learning disabilities or psychological problems, thereby helping teachers adjust their teaching strategies based on the real needs of students. In this way, the use of the Stirling-Darling technique can be an effective step toward improving the quality of teaching and learning in educational environments. Therefore, this research seeks to answer the question of what the intelligent knowledge extraction model in educational environments based on the Stirling-Darling technique is.

### ***Intelligent Knowledge***

Mining Intelligent knowledge mining is a process in which latent information and hidden patterns are systematically extracted from large and complex data. This process involves collecting, analyzing, and modeling data using advanced techniques such as machine learning, artificial intelligence, statistical data analysis, and data mining algorithms. The main goal of intelligent knowledge mining is to discover new patterns, predict trends, and make intelligent decisions based on existing data (Kang et al., 2021). In this process, raw data is collected from various sources such as information systems, databases, and sensors and then processed using various techniques (Guckenbiehl, 2022). This data can be of various types: numerical, textual, visual, or even audio. After processing, analytical models are built to identify specific patterns, complex relationships, and hidden trends in the data. For example, in educational environments, intelligent knowledge mining can be used to identify factors influencing student learning and predict their future performance (Gaire et al., 2019). Intelligent knowledge mining helps organizations make better decisions and optimize their processes. In fact, it allows people and systems to exploit data more effectively and gain new knowledge that was previously unknown (Levallet & Chan, 2019; Salunke et al., 2019; Zieba et al., 2017; Rupčić, 2017).

### ***Educational environments***

Educational environments refer to spaces in which teaching and learning processes take place.

These environments can be physical or virtual and include schools, universities, educational institutions, online courses, and even internships and experiential environments (Sunhare et al., 2020). The main goal of these environments is to provide appropriate conditions for

learning and to enhance the capabilities of students or students. Physical educational environments usually include classrooms, laboratories, libraries, sports halls, and other supportive spaces where students interact with teachers and other students. These environments directly affect the quality of learning, and their appropriate design can increase student motivation and attention (Schmidt et al., 2021).

In today's world, educational environments are increasingly shifting towards digital and virtual (Abdi et al., 2023). Online classes, e-learning platforms, and digital tools such as video conferencing, online forums, and educational software allow students to learn anytime, anywhere. These digital environments have become especially important in times of crisis such as pandemics and have brought greater flexibility to the education process. Educational environments should be designed to cover the diversity of students' needs and learning styles and provide opportunities for interaction and collaboration. In addition, creating an environment that fosters security, social support, and motivation is of great importance (Rojas et al., 2024).

## 2. Method

The present study is a qualitative research in terms of approach and a thematic analysis in terms of method. In the qualitative part of this study, the population studied was university professors in the field of knowledge management. Through purposive sampling, criterion-based sampling, the desired sample was selected and sampling continued until the theoretical saturation of the data was reached. Therefore, the participants in the study included 14 experts and managers. The data collection tool in this study is a semi-structured interview.

The process of analyzing the data obtained from the interview texts, considering its importance in the Atride-Stirling thematic analysis approach, was carried out simultaneously with data collection through three stages of open coding and were classified into themes and subcategories. ATLASTI software was used in the thematic analysis method. Table 1 shows the demographic information related to the interviewees. In thematic analysis, coding and analysis are carried out simultaneously with data collection. With open coding, many themes were obtained, and during the data round-trip process, the initial qualitative data set was reduced to fewer categories.

At this stage, using raw data, preliminary categories related to the indicators of the knowledge extraction model in educational environments were extracted through comparison and analysis of phenomena.

*Table 1. Demographic characteristics of experts*

Row	Gender	Educational degree	Work experience
1	Female	PhD	Between 10 and 15 years
2	Female	PhD	Less than 9 years
3	Female	PhD	Less than 9 years
4	Male	PhD	Less than 9 years
5	Male	PhD	Between 10 and 15 years
6	Male	PhD	Above 26 years
7	Female	PhD	Between 16 and 25 years
8	Male	PhD	Between 10 and 15 years
9	Male	PhD	Less than 9 years
10	Female	PhD	Less than 9 years
11	Male	PhD	Less than 9 years
12	Female	PhD	Between 10 and 15 years
13	Female	PhD	Between 10 and 15 years
14	Male	PhD	Less than 9 years

## 3. Findings

In the present study, the thematic analysis method was used to analyze qualitative data. The thematic analysis method was used to identify the indicators of knowledge extraction model presentation in educational environments. The qualitative data analysis process begins when the researcher identifies and considers meaningful statements and phrases related to the topic. This analysis begins with repeated review and study of the data and is coded after meaningful statements related to the research topic are identified. The practical process of conducting data analysis includes four stages: preparation, familiarization, coding, and obtaining main categories. Interview questions include:

- *What methods and tools are currently used to collect and analyze educational data in your educational center?*
- *What types of data (e.g., grades, class participation, online activities) are collected in the teaching and learning process?*
- *Does your educational center use digital tools to analyze student performance and improve teaching processes? How?*
- *How is the technology infrastructure in your educational center assessed? Are there sufficient tools and systems for data analysis?*
- *What are the problems in accessing modern technologies and analytical tools in your educational center?*
- *Are online learning platforms or learning management systems (LMS) currently used in your educational center? How do these platforms help in the knowledge extraction process?*
- *Are teachers and teaching staff skilled in the use of knowledge extraction and data analysis techniques? What training is provided in this area?*
- *What is the culture of acceptance of technology and modern tools among teachers and students? What are the barriers to using these tools?*
- *Do teachers receive feedback on student performance and use this data to improve teaching?*
- *What are the impacts of environmental and social conditions (such as financial constraints, access to educational resources, and government policies) on the implementation of knowledge mining models in your educational center?*
- *Is there collaboration between educational centers, government, and technology industries to improve IT infrastructure and data analytics?*
- *What kind of supportive policies are there from government or educational institutions to help improve the use of knowledge-mining technologies in your educational centers?*
- *What measures have been taken to improve technology infrastructure and improve access to data analytics tools in your educational center?*
- *Do you think that blended learning environments (face-to-face and online) can help improve knowledge mining and teaching processes? Why?*
- *How can educational processes be optimized using the collected data to lead to better results and more effective learning?*
- *What kind of educational and teaching models can effectively use knowledge-mining techniques?*
- *Have personalized teaching and learning models (based on data analysis) been implemented in your educational center? How?*
- *In what contexts can knowledge extraction models be used to identify problems and weaknesses in the teaching and learning process?*

For the researcher to become familiar with the depth and breadth of the data, it is necessary to immerse himself in them to some extent. Immersion in data usually involves "repeatedly reading the data" and actively reading the data (i.e., searching for meanings and patterns). In this study, coding was done using software. Some of the interviews are mentioned below:

**Table 2.** *References to interviews and some extracted codes*

Interview number	Concepts	Interview Sentences
M1	Commitment Human Resource Management	In knowledge management and knowledge extraction, a big challenge in my opinion in organizations that can be a big obstacle to knowledge being extracted properly in the system and being used and helping the system is the issue of commitment and human capital of the organization.
M1	Human Resource Training Hardware and Software	In terms of software and hardware, everything is okay. You have to have the human resources with you. Then in organizations or at least insurance companies, there is a series of knowledge that has existed since ancient times.

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M1	Motivation Organizational Belonging Team Member Interactions Participation	One of the challenges that must be overcome is the issue of creating motivation, that is, the human capital should be motivated to share its knowledge with you. It may not be obvious, but it happens a lot. They are very unmotivated. In order for them to participate in such a system and to accompany it, motivational discussions are very important.
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The results of the factor analysis show that among the 75 existing indicators (items), 15 basic themes can be identified and 5 categories of constructive themes have been obtained. Based on the literature, background and existing theories, these components were named in the table below.

Table 3. Identification of the overarching theme of presenting a knowledge extraction model in educational environments

Constructive theme	Initial theme	Initial coding	
Foundational Concepts and Theoretical Frameworks	Theoretical Foundations	Definition of the Stirling Darling Technique	
		Historical development of knowledge extraction methods	
		Relationship between intelligent systems and educational environments	
		Theoretical frameworks for knowledge extraction in education	
	Methodological Approaches	Role of machine learning in knowledge extraction	
		Qualitative vs. quantitative methods in knowledge extraction	
		Meta-synthesis as a research method	
		Data collection techniques for educational research	
Technological Integration and Data Management	Technological Integration	Analytical methods for interpreting extracted knowledge	
		Validity and reliability in meta-synthesis studies	
		Use of artificial neural networks (ANNs) in education	
		Application of recurrent neural networks (RNNs)	
	Data Management	Role of clustering algorithms in knowledge extraction	
		Integration of mobile learning technologies	
		Impact of educational technologies on learning outcomes	
		Data privacy and ethical considerations in educational research	
Learning Environments and Pedagogical Strategies	Learning Environments	Data storage solutions for large-scale educational data	
		Techniques for data visualization in educational contexts	
		Management of learner data for personalized learning experiences	
		Strategies for ensuring data integrity and security	
	Pedagogical Strategies	Characteristics of effective learning environments	
		Role of collaborative learning in knowledge extraction	
		Influence of classroom dynamics on knowledge acquisition	
		Strategies for enhancing learner engagement	
Assessment, Evaluation, and Challenges	Assessment and Evaluation	Adaptation of learning environments for diverse learners	
		Active learning strategies supported by technology	
		Inquiry-based learning and its relation to knowledge extraction	
		Differentiated instruction using extracted knowledge insights	
	Challenges and Limitations	Scaffolding techniques in intelligent learning environments	
		Use of formative assessments to guide instruction	
		Methods for assessing knowledge extraction effectiveness	
		Evaluation criteria for educational technologies	
Future Directions, Professional Development, and Community Engagement	Future Directions	Feedback mechanisms in intelligent learning systems	
		Impact assessment of extracted knowledge on student performance	
		Continuous improvement processes based on evaluation results	
		Barriers to implementing intelligent systems in education	
	Professional Development	Limitations of current knowledge extraction techniques	
		Resistance to change among educators and institutions	
		Challenges related to data quality and accessibility	
		Addressing biases in data collection and analysis	
	Community Engagement	Future Directions	Emerging trends in educational technology and knowledge extraction
			Predictions for the future of intelligent systems in education
		Professional Development	Potential research areas within the Stirling Darling framework
			Innovations in machine learning applications for education
			The role of interdisciplinary approaches in advancing research
			Training programs for educators on new technologies
Community Engagement	Importance of continuous professional development		
	Resources available for educators seeking to improve skills		
	Peer mentoring programs focused on technology use		
	Workshops on integrating the Stirling Darling Technique		
Community Engagement	Role of community stakeholders in educational technology initiatives		
	Partnerships between schools and tech companies		
	Engaging parents in the learning process through technology		
	Community resources that support educational outcomes		
Community Engagement	Community Engagement	Strategies for building local support networks	

This categorization provides a clearer structure that encapsulates the various aspects involved in applying the Stirling Darling Technique within intelligent knowledge extraction models in educational settings.

***Quality control of the analysis of the qualitative analysis performed (AtlasTI output)***

Four quantitative criteria were used to examine the validity, transferability, confirmability, and reliability: Holstey coefficient, Scott's p-coefficient, Cohen's kappa index, and Krippendorff's alpha. The correlation of expert opinions by calculating the Holstey coefficient (PAO) or "percentage of observed agreement" was 0.865, which is a significant value. Considering the shortcomings of the Holstey method, the p-Scott index was also calculated, which was 0.805. The fourth index for estimating the validity of qualitative research is Cohen's kappa index. Cohen's kappa index was 0.844 in this study. Finally, Krippendorff's alpha was used, and its value was estimated to be 0.824 in this study.

## **5. Discussion**

In the research based on the Stirling-Darling technique, 75 initial codes were identified in 15 initial themes based on 5 constituent themes. Foundational Concepts and Theoretical Frameworks, Technological Integration and Data Management, Learning Environments and Pedagogical Strategies, Assessment, Evaluation, and Challenges, Future Directions, Professional Development, and Community Engagement are the constituent themes of the knowledge extraction model in educational centers. It can be said that in today's world, intelligent knowledge extraction in educational environments is known as a key tool for improving the quality of teaching and learning.

For the effective use of this technique, paying attention to these main components is an essential condition for improving the state of teaching and learning in educational centers. In this context, for the flourishing and exploitation of the capabilities of intelligent knowledge extraction, it is necessary to create a suitable educational environment and empower various factors, including teachers, students, and administrators.

The first and most important factor in the successful implementation of intelligent knowledge extraction is Technological Integration and Data Management. Having advanced information systems and stable communication networks for data collection and storage is essential. Educational data can be obtained from various sources such as tests, classroom interactions, assignments and online activities. This data requires careful processing and analysis, which is not possible without the right infrastructure. Therefore, investing in IT infrastructure, data storage systems and up-to-date analytical tools is a prerequisite for realizing the goals of intelligent knowledge extraction in educational centers.

In addition, the internal conditions of educational environments also play a vital role in the success of knowledge extraction models. Human factors such as teachers' capabilities in using new technologies, educational organizational culture and interaction between students and teachers can be influential. Creating and clearly defining Learning Environments and Pedagogical Strategies can help in smoothing the application of knowledge extraction by teachers. Therefore, teachers should be familiar with new knowledge extraction techniques and have the ability to interpret data and use their results to improve teaching methods. This requires defining pedagogical strategies, continuous training of teachers, and providing the necessary tools to facilitate the teaching process. In addition, the culture of acceptance and use of technology among administrators and teachers must be strengthened so that the educational environment becomes a suitable space for the implementation of these models. Environmental conditions and external factors such as changes in educational policies, social and economic impacts, as well as access to educational resources, are other factors that must be considered.

In many cases, environmental challenges such as lack of financial resources, limited infrastructure, and social inequalities can prevent the successful implementation of intelligent knowledge extraction models. To overcome these problems, Foundational Concepts and Theoretical Frameworks must be identified and defined. Also, appropriate educational programs, supportive policies, and inter-organizational collaborations must be created to improve the environmental conditions so that intelligent knowledge extraction can be utilized seamlessly.

To improve educational centers and flourish knowledge extraction, this process must be optimized and modernized in coordination with educational institutions, administrators, and teachers. The use of automated learning systems and advanced analytics can significantly help in identifying student needs and improving teaching methods. For example, by analyzing data related to student performance, patterns of weaknesses and strengths can be identified and teaching methods can be optimized specifically for each individual or group. This action not only increases learning efficiency, but also strengthens student motivation. Educational centers with up-to-date Assessment, Evaluation, and Challenges and the right tools can put learning on the right track and clarify the path for the learner.

In the context of applying the Stirling-Darling Technique in an Intelligent Knowledge Extraction Model for Educational Environments, the "Future Directions, Professional Development, and Community Engagement" delves into the potential pathways for advancing the technique in educational settings. It explores further research and development avenues to enhance the efficiency and efficacy of knowledge extraction processes within these environments. Moreover, it emphasizes the importance of continuous professional development for educators and stakeholders to integrate and utilize this intelligent model effectively. Additionally, the section underscores the significance of community engagement in fostering collaboration and sharing best practices to optimize the implementation of the Stirling-Darling Technique for the benefit of students, teachers, and the broader educational community.

## 6. Conclusion

The flourishing of knowledge extraction in educational centers requires attention to all these factors in an integrated manner. Advanced technologies should be used to collect and analyze educational data, and in addition, the internal and environmental conditions of educational centers should be designed and improved in a way that leads to the optimal use of this data. This can help transform educational processes and lead to tangible improvements in the quality of teaching and learning in educational centers. In order to realize the flourishing of knowledge extraction in educational models and improve educational centers, attention to infrastructure, internal conditions, and environmental conditions is of particular importance. In this regard, the following practical suggestions can help improve the knowledge extraction process and enhance the quality of education in educational centers:

- One of the main prerequisites for success in knowledge extraction models is providing appropriate information technology infrastructure. Establishing and upgrading sustainable information networks, purchasing and implementing data analysis software, and creating large databases to store educational data can help facilitate this process. Also, ensuring access to high-speed internet and creating online platforms for data collection and analysis are other essential measures.
- Teachers should acquire the necessary skills to use modern technologies and knowledge extraction tools. It is of great importance to hold training courses and specialized workshops to familiarize teachers with new methods of data analysis and how to use them to improve the teaching and learning process. These trainings should be conducted regularly and with a focus on modern educational techniques.

- In educational centers, the adoption of technology should start at the management level. Managers should be encouraged to use data and smart analytics for optimal decision-making. Creating an organizational culture that focuses on the acceptance and use of new technologies at the teacher and student levels will help to effectively utilize knowledge extraction models.
- Establishing cooperation between educational institutions, the government, and technology industries can provide the financial and technological resources needed to successfully implement knowledge extraction models. The government can provide the necessary educational and financial facilities to implement these models in educational centers by creating supportive policies. Inter-organizational cooperation can help transfer knowledge, share resources, and optimally use experiences between different educational institutions.
- Using educational data analysis, the specific needs of each student can be identified and personalized curricula can be designed for them. Creating intelligent systems that allow teachers to optimize their teaching methods for each student or specific groups of students based on the collected data is one of the key strategies for increasing the efficiency of the educational process.
- To succeed in intelligent knowledge extraction, processes need to be continuously evaluated and monitored. Creating continuous feedback systems from teachers and students can help identify problems and weaknesses in educational processes. These feedback systems can include online evaluation forms, surveys, and consultation sessions between teachers and students. - Educational centers should actively support research projects in the field of knowledge extraction and its applications in education. Creating experimental spaces and encouraging innovation in the use of data to improve teaching and learning methods can lead to the development of new and more efficient methods in the educational process.
- Blended learning models that combine in-person and online learning can be particularly useful in the field of knowledge extraction. These learning environments provide appropriate conditions for collecting and analyzing educational data and allow teachers and students to exploit new technologies to improve the learning process.

### Declaration of Competing Interest

The author declares that he has no competing financial interests or known personal relationships that would influence the report presented in this article.

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