Internet of Things for Smart Education: A Systematic Literature Review

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***Abstract*—The Internet of Things has become a comprehensive concept used in different contexts (*e.g.*, smart cities, security, and education). In particular, in education, a vast literature has used the Internet of Things to promote smart education. However, there is still no overview of how the Internet of Things has been used to promote smart education. We addressed this challenge by conducting a systematic literature review on the use of the Internet of Things to promote smart education. Through a systematic literature review, we answered the following research questions: *i)* Which smart objects collect data from the physical world? *ii)* What types of information are collected? And, *iii)* what are the goals of collecting this data? Our analysis reveals that *i)* the most common smart objects in educational environments include sensors, cameras, ID tags, and wearable devices; *ii)* these devices collect data in twelve main categories, which include everything from microclimatic information to details of the emotional and behavioral state of the actors involved; *iii)* the purpose of this collection is to provide a more effective and personalized educational experience to individual needs. Our findings play a crucial role in educational technologies, establishing a foundation for future research endeavors and providing valuable insights into the use of the Internet of Things to promote smart education.**

***Index Terms*—Internet of Things, smart education, educational technologies, smart classrooms, literature review**

I. Introduction

The Internet of Things (IoT) has transformed classic teaching and learning methods [1], [2]. Integration of IoT smart objects in educational environments represents a new frontier in the field of education [3], [4]. These devices, capable of collecting and processing physical world information, can enrich the educational experience, encouraging more interactive and personalized learning [5]–[7].

The current literature highlights the rising importance of IoT in education [1], [8]. There has been a surge in related publications recently, reflecting an increasing interest in applying IoT in educational contexts [5], [6], [9]. Most studies explore how smart objects can enhance educational processes [7], [10], [11]. However, despite this interest, clarity is still lacking regarding the state of the art, particularly concerning the nature of the data collected by these smart objects and the pedagogical objectives pursued.

We conducted a systematic literature review based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [12], analyzing 135 studies to address: *i)* Which smart objects collect data from the physical world? *ii)* What types of information are collected? And, *iii)* what are the goals of collecting this data?

We identified that *i)* widely deployed smart objects, such as sensors, cameras, ID tags, and wearable devices, actively collect detailed environmental and individual data, *ii)* these devices capture a variety of data types, from microclimate and electricity usage to student activities and engagement, and *iii)* these data collections aim to optimize the infrastructure and the teaching-learning process.

II. Method

To ensure a thorough and rigorous analysis within the context of our study, we employed the PRISMA method [12].

A. Objectives and eligibility criteria

This study centers on analyzing smart objects' state of the art in education, specifically examining the data they collect and the pedagogical objectives pursued. It is structured around three research questions: *i)* Which smart objects collect data from the physical world? *ii)* What types of information are collected? And, *iii)* what are the goals of collecting this data? To answer the research question, we defined the following eligibility criteria:

- **Inclusion criteria**: Primary studies on using smart objects in learning environments, focusing on collecting information from the physical world.
- **Exclusion criteria**: *i)* secondary or tertiary studies; *ii)* short papers; *iii)* studies not subject to peer review; *iv)* studies not published in English.

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The authors utilized generative artificial intelligence (*i.e.*, Microsoft Copilot) to improve the grammatical quality of the text.

B. Information sources and search strategy

In this study, we selected seven databases to shape our search scope, aiming to cover Computer Science and Education studies: ACM Digital Library, ERIC, EI Compendex, IEEE Digital Library, ISI Web of Science, Science Direct, and Scopus. We developed the search strategy using the PICOC method [13]:

- **Population**: Studies detailing the utilization of smart objects in educational environments.
- **Intervention**: Exploring the utilization of smart objects in educational environments for information gathering.
- **Comparison**: Not applicable.
- **Results**: Smart objects and their pedagogical goals.
- **Context**: Studies at the intersection between IoT and education, focusing on smart objects.

After adopting the PICOC method, field experts validated a search string. Table I shows the original search string used.

TABLE I
USER SEARCH STRING

TITLE-ABS-KEY ((“classroom” OR “hybrid learning” OR “e-learning” OR “elearning” OR “vblended learning” OR “m-learning” OR “u-learning” OR “smart learning” OR “education”) AND (“iot” OR “internet of things” OR “smart city” OR “smart cities”)) OR **TITLE-ABS-KEY** (“smart classroom”)

C. Data selection and data collection process

The initial evaluation involved reviewing titles and abstracts to ensure they met the inclusion criteria. We used Parsif.al[1] to identify duplicates and conducted a detailed analysis and data extraction by reading the full articles. Information extracted included: *i)* authors’ names and locations, *ii)* smart objects and analyzed parameters (RQ1 and RQ2), *iii)* addressing the problem and proposing solutions (RQ3). Data collection occurred in August 2021.

III. RESULTS

Initially, we identified 8,870 studies and included 135 eligible studies in the final review after thorough data extraction. The data shows an evolution of publications over the years, beginning with the first study published in 2011. Following this initial milestone, there was a substantial increase from 2018 onwards. The peak of this growth happened in 2019, recording the highest volume. However, there has been a decline since 2020, partly attributed to the global pandemic that emerged in that year. Figure 1 illustrates this evolution over the years.

Our analysis identified studies from 42 countries, highlighting the worldwide scope of research on smart object applications in education. Figure 2 summarizes the publications per country.

[1]https://parsif.al/

Fig. 1. List of Published Studies.

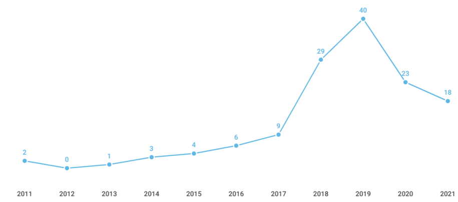
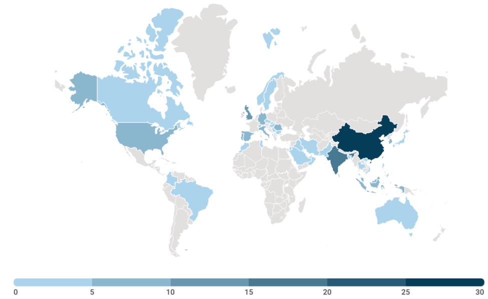


Fig. 2. Global distribution of studies.



A. RQ 1: Which smart objects actively collect data from the physical world?

We identified that sensors (166) are the most prevalent devices widely used to capture environmental and contextual information. Cameras (64) also see widespread use, playing a fundamental role in behavioral observation and analysis. Additionally, ID tags (29) and wearable devices (22) contribute to more diverse and specific data collection about the learning environment and individuals present. Table II shows the prevalence of each device type.

TABLE II
NUMBER OF SMART OBJECTS PER APPLICATION DOMAIN

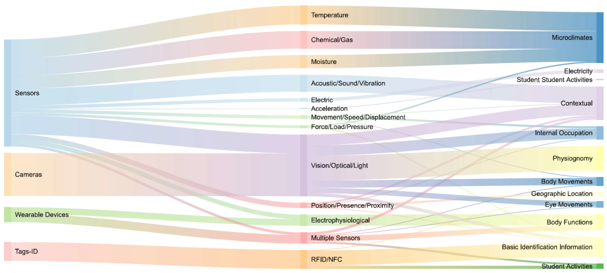
Smart Object	N	Environment	Teachers	Students
Cameras	64	10	7	47
Wearables	22	0	2	20
Sensors	166	108	4	54
ID tags	29	5	1	23
Key: N = number of smart objects				

B. RQ 2: What type of information have people collected?

Smart objects are gathering a variety of information categorized into 12 distinct groups: *i)* microclimatic, *ii)* electricity, *iii)* student activities, *iv)* contextual, *v)* internal occupation, *vi)* physiognomy, *vii)* body movements, *viii)* geographic location, *ix)* eye movements, *x)* bodily functions, *xi)* basic identification information, *xii)* student activities.

Among these categories, microclimatic data stands out for evaluating internal environmental conditions. Contextual and occupancy information provides a holistic perspective of the environment. Data on bodily functions, physiognomy, and movements, including physical and ocular aspects, are vital for evaluating students’ emotional and behavioural states. The gathered information includes intricate details about student engagement. Additionally, electricity consumption data proves relevant for optimizing resources in automated classrooms. Figure 3 presents a Sankey diagram, showing smart objects on the left, classifications in the middle, and data collected on the right.

Fig. 3. Flows of Information Collected by Smart Objects



Objectives	N	Studies
Automation and Systemic Efficiency	14	S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14
Comfort and Environmental Quality	10	S15, S16, S17, S18, S19, S20, S21, S22, S23, S24
Space Management and Occupancy	6	S25, S26, S27, S28, S29, S30
Energy Management and Efficiency	14	S31, S7, S8, S9, S3, S11, S32, S33, S34, S35, S36, S37, S38, S39, S40
Security and Risk Prevention	3	S15, S41, S42
Teaching Assessment and Improvement	4	S43, S44, S45, S46
Class Monitoring and Feedback	4	S47, S48, S49, S50
Impact of Teacher Dynamics	1	S51
Assessment of the Teaching-Learning Process	13	S52, S53, S54, S55, S56, S57, S58, S59, S60, S61, S62, S63, S64
Behavioral and Emotional Analysis	34	S65, S66, S67, S68, S69, S70, S71, S72, S73, S74, S75, S76, S77, S59, S78, S79, S80, S61, S81, S82, S83, S84, S85, S86, S87, S69, S88, S89, S90, S91, S92, S93
Engagement and Participation	9	S94, S95, S96, S97, S98, S99, S100, S101, S102
Prevention and Academic Integrity	8	S54, S70, S103, S104, S105, S106, S107, S108
School attendance management	28	S101, S54, S109, S70, S108, S93, S110, S111, S112, S113, S114, S115, S116, S117, S118, S119, S120, S121, S122, S123, S124, S125, S126, S127, S128, S129, S130, S131
Learning Environment Management	5	S109, S132, S133, S134, S135

Key: N = number of studies in each objective.

TABLE III
OBJECTIVES PER STUDIES

C. RQ 3: What are the objectives pursued through this data collection?

The objectives focus on enhancing and personalizing the educational experience to meet individual needs, including: automation and systemic efficiency for more agile, less error-prone operations; comfort and quality of the environment, aiming for a more pleasant and productive space; efficient management of space and occupancy, optimizing the use of available areas; energy management for cost reduction and sustainability; security and risk prevention, ensuring physical and data integrity; and in the educational sphere, it aims to improve teaching through the evaluation and improvement of pedagogical methods, class analysis, and feedback, the impact of teacher dynamics, analysis of the teaching-learning process, behavioral and emotional analysis, student engagement and participation, prevention and academic integrity, learning environment management, and school attendance management. Table III details these objectives further.

IV. Concluding Remarks

Through our thorough analysis, we unveiled that incorporating smart objects enriches the educational experience, streamlines infrastructure, and enhances the teaching-learning processes. Our research highlights the importance of collecting data to address the individual needs of students and teachers and promoting safe and efficient learning environments. As a future study, we aim to delve deeper into the research questions and propose a research agenda for upcoming studies.

Appendix

The study dataset can accessed from this link: https://osf.io/szd9t/

References

[1] M. Mircea, M. Stoica, and B. Ghilic-Micu, "Investigating the impact of the internet of things in higher education environment," *IEEE Access*, vol. 9, pp. 33 396–33 409, 2021.

[2] F. R. Al-Amoush, "Internet of things in education," *Available at SSRN 3137982*, 2018.

[3] G. Kiryakova, L. Yordanova, and N. Angelova, "Can we make schools and universities smarter with the internet of things?" *TEM Journal*, vol. 6, no. 1, p. 80, 2017.

[4] J. Marquez, J. Villanueva, Z. Solarte, and A. Garcia, "Iot in education: Integration of objects with virtual academic communities," in *New advances in information systems and technologies*. Springer, 2016, pp. 201–212.

[5] M. Kassab, J. DeFranco, and P. Laplante, "A systematic literature review on internet of things in education: Benefits and challenges," *Journal of Computer Assisted Learning*, vol. 36, no. 2, pp. 115–127, 2020.

[6] M. K. Saini and N. Goel, "How smart are smart classrooms? a review of smart classroom technologies," *ACM Computing Surveys (CSUR)*, vol. 52, no. 6, pp. 1–28, 2019.

[7] L.-S. Huang, J.-Y. Su, and T.-L. Pao, "A context aware smart classroom architecture for smart campuses," *Applied Sciences*, vol. 9, no. 9, p. 1837, 2019.

[8] M. Al-Emran, S. I. Malik, and M. N. Al-Kabi, "A survey of internet of things (iot) in education: Opportunities and challenges," *Toward social internet of things (SIoT): Enabling technologies, architectures and applications: Emerging technologies for connected and smart social objects*, pp. 197–209, 2020.

[9] D. D. Ramlowat and B. K. Pattanayak, "Exploring the internet of things (iot) in education: a review," in *Information Systems Design and Intelligent Applications: Proceedings of Fifth International Conference INDIA 2018 Volume 2*. Springer, 2019, pp. 245–255.

[10] R. de Amorim Silva and R. T. V. Braga, "Enhancing future classroom environments based on systems of systems and the internet of anything," *IEEE Internet of Things Journal*, vol. 7, no. 10, pp. 10 475–10 482, 2020.

[11] M. Abdel-Basset, G. Manogaran, M. Mohamed, and E. Rushdy, "Internet of things in smart education environment: Supportive framework in the decision-making process," *Concurrency and Computation: Practice and Experience*, vol. 31, no. 10, p. e4515, 2019.

[12] M. J. Page, J. E. McKenzie, P. M. Bossuyt, I. Boutron, T. C. Hoffmann, C. D. Mulrow, L. Shamseer, J. M. Tetzlaff, E. A. Akl, S. E. Brennan *et al.*, "The prisma 2020 statement: an updated guideline for reporting systematic reviews," *Systematic reviews*, vol. 10, no. 1, pp. 1–11, 2021.

[13] W. S. Richardson, M. C. Wilson, J. Nishikawa, R. S. Hayward *et al.*, "The well-built clinical question: a key to evidence-based decisions," *Acp j club*, vol. 123, no. 3, pp. A12–A13, 1995.