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Sustainable development marketing in education: Implementation of SMART technologies in the educational process

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Abstract. The relevance of this study stems from the exploration of potential approaches to the management of higher education institutions in the context of the ongoing digitalisation and informatisation trends shaping contemporary society. The study aimed to develop an approach for structuring the educational process in an institution through the application of SMART technologies (Specific, Measurable, Assignable, Realistic, Time-Related) to enhance the quality of education. The study employed a methodology combining distinct mathematical models from the theory of digital automata. This approach enabled the implementation of a tailored algorithm for surveying devices within the monitoring zone. It also incorporated methods of synthesis, economic analysis, logical generalisation, as well as graphical and bibliographic techniques for the visualisation of results. The scope of the study included educational institution network infrastructure (such as cameras and environmental monitoring sensors) and individual electronic devices used by participants in the educational process, including smartphones, tablets, and smartwatches. An environment of a "smart educational institution" was established, enabling decision-making support based on data from SMART devices and ensuring feedback aligned with students' needs. The feature of distributed data processing was implemented using an additional managed switch, with its control modified based on automata theory. The proposed approach was tested at the State Tax University (Irpin) through the voluntary participation of second- to fourth-year bachelor's degree students in March-April 2024. The results obtained were compared to those achieved without the use of SMART devices and demonstrated a 1.2% improvement in the quality of educational services. This enhancement was attributed to improved attendance rates and increased engagement of higher education students in the knowledge acquisition process. The practical significance of this study lies in the potential application of the proposed solution to enhance the quality of educational services in higher education institutions, contributing to increased consumer satisfaction

Keywords: digitalisation of education, monitoring of educational service delivery, distributed data processing, management information exchange, transition matrix, input signal

INTRODUCTIONS

The accessibility of modern information technologies has significantly expanded the possibilities for collaboration, remote work, learning, and skill development within a specific institution or under the guidance of a particular specialist anywhere in the world. The digitalisation of society has created the conditions for changing the processes of managing the production of goods and services, minimising subjective influence on managerial decisions. Based on the research of S. Hunt *et al.* (2022), the trajectory of an educational institution can be defined as a line of movement in the plane of service development during the coordination of work, aimed at identifying and meeting the needs of the consumer.

Research by N. Fedchyshyn *et al.* (2024) highlighted that Ukrainian higher education institutions have yet to fully grasp the potential of framing education as a service, requiring appropriate management approaches and a market- and consumer-oriented focus to enhance

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quality. Instead, a fragmented, localised approach to institutional management has been prevalent, as emphasised by O. Hurenko *et al.* (2024), without sufficient consideration of the trajectory component. However, as demonstrated by S. Stephens & C. McLaughlin (2020), the application of management approaches in education, alongside information technologies – particularly those that are SMART – can radically transform motivation, behaviour, the content of educational programs, and the formation of individual learning trajectories. According to Qu. Brown (2021), SMART technology in education can be understood as a specific approach to self-monitoring, analysis, and reporting using computer systems and microprocessors to perform daily tasks involving real-time information exchange. These technologies encompass networks of devices designed to animate static physical objects, smart connected devices (e.g., security cameras, smartphones, tablets), and smart devices capable of limited automation without requiring Internet connectivity (e.g., appliances programmed to operate at specific times). Various management strategies have been incorporated into projects for implementing "smart classrooms and laboratories", which have begun to be partially introduced in Ukraine, as noted in the studies of J. Yershova & L. Bazhan (2020), D. Bugayko *et al.* (2024).

Several European countries have been successfully using SMART technologies to manage the trajectory of educational institutions for quite some time. This has enabled the adaptation of learning systems to the practices of Swiss firms, as evidenced by the research of G. di Maio *et al.* (2020). Educators in Sweden were initially concerned about the pace of internationalisation in education but later shifted the trajectory of educational service management towards a competitive approach using modern information and communication technologies, as analysed by I. Hammar & H. Östh Gustafsson (2022). In Norway, the trajectory of modern education management is based on gender equality, promotional opportunities, ambition, and professionalism, as stated by I. Drake & S. Svenkerud (2024). The latter factor specifically includes the ability for self-control and the desire to master the potential functions of modern information technologies, which aligns with the SMART concept. While the studies reviewed presented general concepts, they did not provide specific algorithms or proven practical approaches to managing educational services using SMART technologies. This has hindered implementation and led to the formal reproduction of individual processes, thus slowing down institutional development.

Therefore, this study aimed to develop an approach for constructing the trajectory of an educational institution using SMART technologies to improve the quality of the educational process. To achieve this goal, the following objectives were set: to develop an algorithm for managing institutional development through trajectory construction, self-monitoring, analysis, and reporting to improve the quality of educational services; to present an implementation tool for a complex task with several constraints and a mathematical apparatus for practical implementation.

MATERIALS AND METHODS

The approach to structuring the trajectory of an educational institution using SMART technologies was based on the application of specific mathematical models from the theory of digital automata. These models were employed to algorithmise the process of polling additional managed switches within the institution's network, recording the results, and supporting managerial decision-making. This facilitated feedback provision tailored to students' needs and addressed challenges arising during the delivery of educational services, ensuring their alignment with efficiency criteria. Specifically, a finite logic model was utilised to cycle through states under specified constraints and conditions, alongside transition models of abstract automata, such as the Moore machine (Hopcroft *et al*., 2001). To evaluate encoding, a coding efficiency coefficient was introduced: $K_{eff} = W/P$, where P is the total number of automaton transitions, and W is a weight function:

$$W = \Sigma t_{ij}, \tag{1}$$

where t_{ij} is the Hamming distance (Guth, 2020) between the state codes a_i and a_j, indicating the number of memory elements that change state during a given transition.

In determining the weight function, summation was performed across all transitions of the automaton. The efficiency coefficient facilitated the evaluation of the complexity of the automaton's combinational circuit. The lower the coefficient value, the less complex the circuit, with the optimal value being $K_{eff} = 1$. A heuristic state encoding algorithm was employed to minimise the total number of memory element changes across all transitions. The algorithm followed these steps:

1. A matrix M was constructed, consisting of all pairs of transition numbers (a_r, b_r) of the automaton.

2. The rows of the matrix were rearranged such that each subsequent row contained at least one element from the previous rows.

3. States from the first row of matrix M were encoded as follows: $Ka_1 = 00...00$, $Kb_1 = 00...01$, where Ka, Kb are the code of the respective row in the matrix, denoted by lowercase letters.

4. The first row of matrix M, containing the encoded states, was removed, resulting in a new matrix M'.

5. Due to step 3, one element was encoded in the initial row of matrix M'. An unencoded element was selected from the first row of matrix M' and denoted as γ.

6. Matrix $M\gamma$ was constructed by selecting from matrix M' the rows containing γ. It is assumed that $M\gamma = \{\gamma_1, \gamma_2, \ldots, \gamma_f, \ldots, \gamma_F\}$ is the set of elements from matrix $M\gamma$ that have already been encoded. Their codes are denoted by $K\gamma_1, K\gamma_2, \ldots K\gamma_f$, respectively.

7. For each $K\gamma_f (f = 1, 2, \ldots, F)$, a set of codes $C^1_{\gamma f}$ was identified. This set consists of codes at a Hamming distance of 1 from $K\gamma_f$, which have not yet been used for encoding the states of the automaton. Based on this, the set D was constructed:

$$D_{\gamma}^{1} = \bigcup_{f=1}^{F} \cdot C_{\gamma f}^{1}, \quad (2)$$

where f is the indices of the codes for each element K in the matrix set; γ is an element of the matrix; $C_{\gamma f}^{1}$ is the set of codes whose code distance from the code $K_{\gamma f}$ is equal to 1.

If $D_{\gamma}^{1} = 0$, then a new set is constructed, which is analogous to the previous one:

$$D_{\gamma}^{2} = \bigcup_{f=1}^{F} \cdot C_{\gamma f}^{2}, \quad (3)$$

where $C_{\gamma f}^{2}$ is the set of codes whose code distance from the code $K_{\gamma f}$ is equal to 2.

If $D_{\gamma}^{2} = 0$, it is constructed D_{γ}^{2} until $D_{\gamma}^{2} \neq 0$ is found.

8. It is assumed that $D_{\gamma}^{2} = \{K_{\gamma 1},\dots, K_{\gamma g},\dots, K_{\gamma G}\}$.

9. For each $K_{\gamma g}$ calculate $w_{gf} = |K_{\gamma g} - K_{\gamma f}|^2$, which is the Hamming distance between $K_{\gamma g}$ and all used codes $K_{\gamma f}$ $(f = 1, 2, \dots, F)$. Here w is the Hamming distance, $K_{\gamma g}$ are the codes of the elements of matrix $M\gamma$ for $D_{\gamma}^{2} \neq 0$; $K_{\gamma f}$ are the codes of the elements of the matrix $M\gamma$ for constructing the initial set D.

10. It is calculated $w_g = \Sigma_{f\text{-}1}^{F} \cdot w_g$, $(g = 1,\dots, G)$.

11. From D_{γ}^{2} is selected K_{γ} for which is true $w_g = w_{gmin}$. Element γ is encoded with code K_{γ}.

12. From the matrix M' the rows in which both elements are encoded are deleted, resulting in a new matrix, also denoted as M'. If there is no row left in matrix M' proceed to step 12, otherwise, proceed to step 5.

13. Using equation (1), the function $w = \Sigma t_{ms}$, where $t_{ms}|K_m - K_s|^2$. Where w is the Hamming distance, t is the Hamming distance between the codes of states a_i and a_j, which is equal to the number of memory elements changing their state during the studied transitions, and K is the code mark on the corresponding transition.

14. End.

The approach to managing the trajectory of an educational institution using SMART technologies was tested by integrating devices, sensors, and surveillance cameras (manufactured by various brands, including Samsung, TP-LINK, Hikvision, and others of Chinese and South Korean origin) into a unified network. This integration was achieved via additional managed switches (MikroTik CRS328-24P-4S+RM, Latvia, running RouterOS), with modifications enabling query mirroring to other network devices without interfering with users' private information. The testing was conducted at the State Tax University in Irpin, involving second- to fourth-year bachelor's degree students during in-person attendance in classrooms equipped with SMART devices connected to the system.

A total of 160 students participated in the pilot study. During the testing, proprietary software developed specifically to implement the proposed method was utilised for managing transitions between devices, alongside SMART Remote Management for overseeing the institution's SMART devices and Internet Security Systems scanners to ensure network device security. Students' personal SMART devices were connected voluntarily; however, most participants supported the experiment and actively tested the technology. The testing was conducted in March-April 2024, comparing the outcomes of one month of operation with connected SMART devices against a month in standard mode. The experiment adhered to ethical principles for research involving human participants, in compliance with the norms and regulations of the Declaration of Helsinki (1964).

Analysing the modern educational institution, it was found that devices and systems (such as sensors monitoring critical parameters, Wi-Fi networks, access to digital libraries, knowledge control and assessment systems, and online learning platforms) could be integrated to perform management functions and support development tasks. Considering the requirements of governmental, educational, social, and socio-psychological directions for the development of territorial communities, as outlined in the Order of the Ministry of Development of Communities and Territories of Ukraine No. 172 "On the Approval of the Procedure for the Formation of the Concept of Integrated Development of the Territory of the Territorial Community" (2022), such management approaches should be implemented across all areas of state activity, including education. This would enable the delivery of educational services to be structured according to the criterion of efficiency.

The implementation of the "smart" technology was examined through several technical innovations. All staff members of the educational institution were assigned an ID number embedded in a SMART card containing a data chip. This card served simultaneously as an employee identification card and an electronic access key to offices and laboratories. Students were assigned their ID numbers based on the identifiers of their SMART devices, such as smartphones, tablets, or smartwatches, which they carried with them at all times. Each individual was assigned a unique ID, which was recorded in the institution's information system database. Additional managed switches were integrated into the institution's existing network and programmed to register students' SMART devices without accessing the personal data stored on those devices. Upon entering the institution, a student's SMART device automatically connected to the Wi-Fi network and was logged into the institution's information system. Data collected from the SMART devices were mapped to the institution's floor plan, identifying the location of users in specific classrooms or laboratories during sessions. This information was cross-referenced with the class schedule to track attendance.

In the final stage, specific events were recorded for subsequent processing and decisionmaking to adjust the institution's trajectory. Surveillance cameras were connected to the educational institution's network via additional managed switches, which operated on the principle of a digital automaton. These switches transmitted signals and received mirrored responses, functioning based on a protocol of random instantaneous recordings of specific areas where registered IDs were detected. This protocol was founded on the algorithms of digital automaton theory within Industry 4.0 technologies (de Oliveira *et al.*, 2024), incorporating machine learning (Tancredi *et al.* 2022). It facilitated the controlled recording of photos, videos, and audio during educational activities.

RESULTS AND DISCUSSION

It was found that the collected information is assigned to a specific employee/classroom and can be reviewed by the responsible person (staff member or lecturer) at the end of the session by logging in with their ID to the folder where the materials are stored. Once the materials have been analysed, the responsible person can delete them or archive them. Thus, in the course of the study, the main goals of the developed SMART technology were established for different groups of educational service consumers (Table 1).

Table 1. Goals of the SMART technology

Consumer groups	Monitoring attendance of staff and students without interfering in the educational process or infringing on personal freedoms	Implementing selective monitoring of educational quality	Supporting feedback within the institution's communication system
Learners	-	+	+
Lecturers	-	+	+
Institution managers	+	+	+
Stakeholders	-	+	-

Source: created by the author

It was established that the aforementioned outcomes are achieved by connecting additional managed switches to the network, creating mirroring bridges. The implemented technical measures were found to enable several functions. If less than 50% of the students are present in a classroom, a long-duration video recording of the session begins. For instance, the lecturer receives a notification on their SMART device about the recording, while students receive a reminder on their SMART devices from the electronic information system about the need to complete a survey regarding the quality of teaching and course materials where low attendance was recorded. This reminder will disappear only after the student completes the online survey, which is recorded in the institution's system using the student's ID.

It was found that the recorded class sessions and student survey responses are accessible to authorised personnel in the quality assurance department for analysis and discussion. Surveillance cameras in non-working areas (corridors, stairwells, library, cafeteria, etc.) are activated by motion sensors and transmit event recordings to the institution's database through switches in case of increased noise levels or fire alarms. In other situations, cameras are activated periodically according to a schedule set in a digital state machine to monitor areas with high occupancy, while electronic fire safety devices, water supply monitoring systems, and air temperature sensors operate continuously and transmit relevant information to the central system without switches, implementing the concept of a "smart" institution analogous to a "smart home" (Setz *et al.*, 2021).

It was argued that by recording staff and students in the institution's information system, it becomes possible to facilitate feedback through a dedicated page on the institution's internal portal accessible via SMART devices. Here, users can ask questions of administrative staff, contact lecturers or other university staff, request books from the library, obtain references from accounting or HR departments, adjust their own educational trajectories, or submit absence requests. In response, users receive a notification on their SMART device indicating the date and time when the requested document will be ready or the reference number of the recorded request. This approach has enabled the systematisation of information by discipline, lecturer, and student, which in turn has provided the basis for developing additional measures or changes to the content and list of educational components, thus shaping the institution's development trajectory in response to market demands. The distributed information processing was based on the use of an additional managed switch within the system, whose control was modified based on automata theory. This involved partitioning all states of the initial abstract automaton into classes of equivalent states that do not intersect pairwise and replacing each equivalence class with a single state (a class representative). As a result, a minimal automaton was obtained with the number of states equal to the number of equivalence classes of the input state partition.

The essence of this approach was as follows: transitions and outputs between individual devices and network sensors were defined in tabular form. Surveillance cameras and user SMART device identifiers were considered, divided into input signals from SMART devices and formed into sets based on student groups (alphabetical units). A transition and output table was then constructed, which determined when to activate the surveillance camera in a particular classroom or laboratory and transition to another set with the same or fewer alphabetical units. An implementation example was developed and presented for a complex scenario involving four classrooms, three corridor cameras, and several registered "smart" devices analysed by the system (Fig. 1).

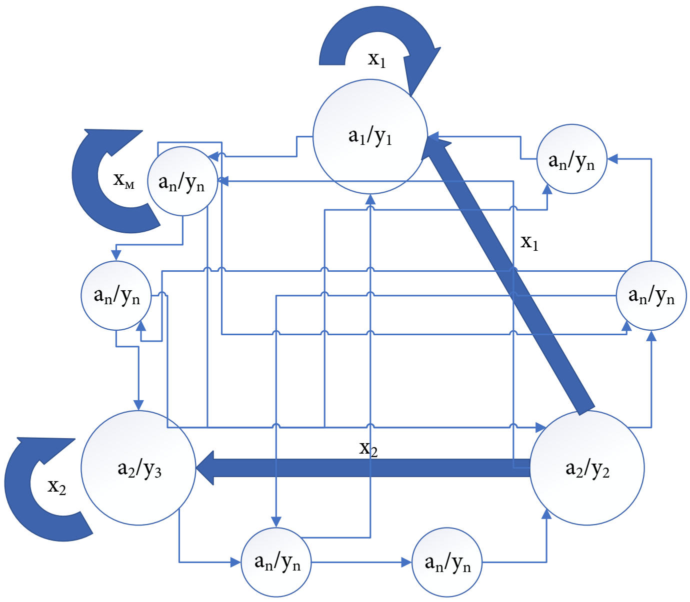

Figure 1. Generalised transition graph of the abstract automaton for implementing the approach to constructing the trajectory of managing an educational institution using SMART technologies
Source: created by the author

The camera transition graph is designed to ensure that all classrooms and student groups receive equal monitoring throughout the day, regardless of the order in which student groups move between classrooms. The automaton inputs (input signals from SMART devices), shown in Figure 1, form sets denoted as $a_{1\text{-}}a_n$; SMART devices, along with users, move between classrooms denoted as $y_1 y_n$; camera transitions are denoted as $x_{1\text{-}}x_3$ in the diagram. For simplicity, it is assumed that there are three cameras: $x_{1\text{-}}x_3$.

It was found that the number of classrooms, groups, and devices can vary. To algorithmically solve the problem presented in Figure 1, a transition from an abstract automaton to a structural one is used, followed by the interpretation of the logical scheme through the encoding of input, output signals, and internal states of the automaton using sets of variables. To encode input signals, the set of input signals $X = \{x_1, x_2, \ldots x_M\}$ is written, which is encoded by vectors $K_{in} = int(log_2 M)$, where *int* is rounding to the nearest larger integer, and M is the cardinality (number of symbols) of the input alphabet. The encoding of input signals is arbitrary.

The output signals of the automaton $Y = \{y_1, y_2, \ldots y_S\}$ are encoded by a vector of length $K_{out} = int(log_2 S)$, where S is the cardinality of the output alphabet. The encoding of output signals can be implemented using the following algorithm:

1) Each output signal y_i is associated with an integer $P^i i$, equal to the number of occurrences of the signal y_i in the automaton's output table.

2) The numbers P_i are ordered in descending order.

3) The output signal y_i with the highest weight ($P_i max$) is encoded with a code containing all zeros (00...00).

4) The next L output signals (where L is the number of bits in the binary vector of the output signal), in descending order of weight according to step 2, are encoded with codes containing one unit (00...01, 00...10,... , 10...00).

5) To encode the following output signals in descending order, all codes containing two units are used, then three units, and so on, until all output signals are encoded.

As a result, an encoding is obtained where the more often an output signal occurs in the output table, the fewer units are contained in its code. This approach is necessary to simplify the algorithmisation of the processes of software implementation of the approach to building the trajectory of an educational institution using SMART technologies. Directly, the state of the automaton $A = \{a_1 a_2 \ldots a_R\}$ is encoded by a vector of length $K_{state.} = int(log_2 R)$, where R is the cardinality of the state alphabet. It should be noted that the length of the state code vector also determines the number of memory elements (triggers) of this automaton.

Consequently, encoding internal states with binary symbols significantly influenced the cost of the combinational part of the automaton circuit. Optimal encoding yielded minimal costs when connecting all SMART devices to the network. Under this criterion, the complexity of the circuits implementing disjunctions at the inputs of memory elements decreased, i.e., the combinational circuit of the automaton was minimised. Students of higher education participating in the experiment noted that the ability to quickly resolve several issues significantly facilitated the educational process, modernised it, and made it more engaging. Moreover, the presence of attendance monitoring significantly stimulated responsibility and improved attendance quality.

It was asserted that a "smart" educational institution is an element of a smart city. As M. Murroni *et al.* (2023) point out, that smart cities and 6G technologies have the potential to transform lifestyle and work patterns in the coming years, thereby increasing attention to the concept of managing educational services using SMART technologies. This claim is supported by the authors based on market research and a reassessment of the entire wireless communications sector. From a technical perspective, this requires addressing several issues, such as compatibility, data privacy, security, the digital divide, and implementation challenges. The development of this field will require specialists who are already working in such environments (Murroni *et al.*, 2023).

While the latest research may seem somewhat futuristic, given the lifecycle of any service in an intensely competitive and innovative environment, the trends outlined can be substantiated (Zhang *et al.*, 2020; Mancini *et al.*, 2021; Oliva *et al.*, 2022). Furthermore, T. Zhang *et al.* (2020) indirectly pointed to the potential of SMART technologies to ensure educational sustainability, a notion corroborated by the research of E. Nica *et al.* (2021) on the use of information technology in education in the context of the COVID -19 pandemic. Their study analysed the resilience of online learning methods by examining students' attitudes towards academic disciplines. The authors emphasised that, regardless of changes in the world or society, sustainable development in education is crucial. Their findings illustrate that while online learning can be successfully implemented in universities in the short term, a long-term perspective demands the development of a hybrid system based on blended learning, utilising modern technologies that can swiftly adapt to the changes of a dynamic environment and ensure educational sustainability. Other researchers, such as M. Caeiro-Rodriguez *et al.* (2021), have highlighted the need for continued intensive technological development in shaping higher education services, with a focus on information exchange, which they define as a European perspective.

A similar approach to managing not only individual educational institutions but the entire education sector, as described in this study, has been elaborated upon by researchers N. Vinogradova *et al.* (2020). Specifically, these researchers drew a parallel between the formation of a knowledge economy and the creation of an information and communication technology environment. In this context, SMART technologies serve as a trajectory for building the future educational model of higher education, as they enable flexible changes in the learning process, allowing for adaptability, personalisation, continuity, multidimensionality, and systematic approaches.

The concept of constructing trajectories for educational institutions has been extensively researched in publications by Chinese scholars, as evidenced by the articles of F. Yang *et al.* (2022) and Y. Can & A. Hou (2021). In the research of Y. Can & A. Hou (2021), it was noted that since 2014, the Chinese government has been actively developing policies to promote the development of the Internet and encourage the participation of students from remote areas of the country in education, as well as international student mobility. The existing policy comprehensively utilises supply-oriented, environment-oriented, and demand-oriented instruments. The latter two instruments are used more frequently and effectively, as noted in the study of F. Yang *et al.* (2022), due to the increasing use of modern communication tools by the population. The findings support the argument made by scientists that the analysis of an institution's development trajectory is fully correlated with access to modern information and communication technologies. The Internet and the tools oriented towards supply, environment, and demand allow for the rapid modification of educational service delivery paths and encourage students to engage with the SMART technologies available within the institution. It is difficult to agree that the pressure for liberalisation in education compels countries to adapt their educational systems, but it is easier to agree that the use of modern technologies in education is influenced by market demands (Can & Hou, 2021). In this context, it is also hard to dismiss the multilayered approach that facilitates the creation of short paths through the use of SMART technologies, while simultaneously expanding the sphere of collaboration with employers. Therefore, it is possible to agree with and significantly extend the research by N. Vinogradova *et al.* (2020) concerning the formation of a knowledge economy through SMART technologies.

The identified prospects of interaction and mutual influence of SMART technologies, which have found implementation and mathematical grounding in the proposed approach, can be used to construct new higher education models. This is not only due to the "convenience" and attractiveness of technological innovations, as defined by researchers N. Vinogradova *et al.* (2020), but, further building on this, it enables the formation of professionals capable of addressing issues swiftly and efficiently, utilising the latest developments and an understanding of the historical connections. This, in turn, supports the assertions made by T. Zhang *et al.* (2020) regarding the competition of innovations, with an emphasis on innovations in education that shape educational services, responding promptly to changes in their lifecycle.

When comparing the present research with the studies of T. Zhang *et al.* (2020) and M. Caeiro-Rodriguez *et al.* (2021), it cannot be agreed that the use of new technologies to build the trajectory of an educational institution and the application of SMART technologies for this purpose is solely a European perspective. M. Caeiro-Rodriguez *et al.* (2021) provided an example of higher education institutions in Greece, Estonia, Denmark, Portugal, and Spain, where, in addition to the best practices of using SMART technologies in managing educational services, challenges related to student communication were noted. However, T. Zhang *et al.* (2020) highlighted the potential for ensuring the sustainability of education, which also involves the development of communication skills, as confirmed by the study described in this research. As a result, students who participated in the experiment significantly increased their communication with lecturers and administrative staff, as they gained the opportunity to receive answers to questions, prompt feedback, and enhanced communication among participants in the educational process. This was corroborated by the increased attendance at consultations and the number of new registrations for additional consultations and electives.

CONCLUSIONS

During the course of the research, an algorithm for managing the development of an educational institution through the construction of a management trajectory was developed. The information required to create this trajectory was gathered using SMART devices from the participants in the educational process. The mathematical framework allowed this approach to be adopted as a foundation for creating similar systems in other higher education institutions across Ukraine. Effective feedback within the educational institution not only facilitated the clear construction of the institution's trajectory but also contributed to the improvement of the educational service itself by increasing engagement and enabling participants in the educational process to access information in real-time. Moreover, the feedback between students and lecturers or the institution's administration enables management according to effectiveness criteria, as the information used for decision-making is not only timely but also systematised, thereby minimising the time spent on information processing.

Comparing the aforementioned approach with the experience of countries considered in the analysed academic sources, it is possible to highlight the undeniable advantages of the proposed approach: realism and optimality, which, when combined with real-time operation, demonstrate the effectiveness of SMART technologies, as they align with the SMART criteria outlined in the concept. A limitation of the studies reviewed is the relatively small number of transitions for operating SMART devices, which may result in the loss of some data packets and delays in processing the received information. This can be minimised by expanding the network of SMART devices and transmitting all data for processing in cloud services. These conclusions have allowed for the identification of promising research directions on this topic, namely: determining the development of soft skills when applying SMART technologies in managing the educational process, and developing adjustments to "services by design" using SMART technologies for monitoring the professional development of graduates, as the latter involves gathering information about practical experience, which depends on the evaluation of students' expectations. On this basis, it is possible not only to improve specific educational components but also to introduce new courses aligned with the demands of the time.

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CONFLICT OF INTEREST

None.

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Маркетинг сталого розвитку у сфері освіти: імплементація SMART-технологій у навчальний процес

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Анотація. Актуальність роботи була зумовлена дослідженням можливих підходів до управління закладами вищої освіти в контексті тенденцій цифровізації та інформатизації процесів функціонування сучасного суспільства. Метою роботи була розробка підходу побудови освітнього процесу навчального закладу за допомогою SMART-технологій (Specific, Measurable, Assignable, Realistic, Time-Related) для покращення якості освітнього процесу. В роботі було використано підхід, що об'єднує окремі математичні моделі теорії цифрових автоматів та дозволяє опитувати за розробленим алгоритмом пристрої, які знаходяться у зоні моніторингу, разом з методами синтезу, економічного аналізу, логічного узагальнення, а також графічним та бібліографічним методами для унаочнення результатів (обладнання мережі навчального закладу – камери та датчики контролю середовища, індивідуальні електронні пристрої учасників освітнього процесу – смартфони, планшети, розумні годинники тощо). Було сформовано середовище «розумного навчального закладу», де відбулася підтримка прийняття рішень на основі інформації зі SMART-пристроїв та забезпечення зворотного зв'язку за потребами студентів. Особливість розподіленої обробки інформації була реалізована за допомогою додаткового керованого комутатора, в керування яким було внесено зміни на основі теорії автоматів. Апробація підходу відбувалася у Державному податковому університеті (м. Ірпінь) за допомогою добровільної участі здобувачів освіти 2-4 курсів освітнього рівня «бакалавр» у березні-квітні 2024 року. Отримані результати порівнювалися з результатами роботи, отриманими без задіяння SMART-пристроїв та показали зростання якості надання освітньої послуги на 1,2 % завдяки покращенню якості відвідування та активізацією участі здобувачів вищої освіти в процесі отримання знань. Практична цінність даної роботи полягає у можливості застосування даного рішення для підвищення якості освітньої послуги у вищих навчальних закладах, що сприяє зростанню задоволеності споживачів послуги

Ключові слова: цифровізація освіти, моніторинг виконання освітніх послуг, розподілена обробка інформації, обмін інформацією управління, матриця переходів, вхідний сигнал