International Journal for Innovation Education and Research

ONLINE ISSN: 2411-2933 PRINT - ISSN: 2411-3123

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Alexandre Stürmer Wolf;Jorge Luis Victória Barbosa

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Published Date: 9/30/2019 **Page.241-250** **Vol 7 No 9 2019**

DOI: https://doi.org/10.31686/ijier.Vol7.Iss9.1741

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Alexandre Stürmer Wolf
Programa de Pós-Graduação em Computação Aplicada - PPGCA
Universidade do Vale do Rio dos Sinos (Unisinos)
Av. Unisinos, 950, São Leopoldo, Brasil
+55 (51) 3037-1000 wolfalexandre@gmail.com

Jorge Luis Victória Barbosa
Programa de Pós-Graduação em Computação Aplicada - PPGCA
Universidade do Vale do Rio dos Sinos (Unisinos)
Av. Unisinos, 950, São Leopoldo, Brasil
+55 (51) 3037-1000 jbarbosa@unisinos.br

Abstract

This article presents an application based on a computational model for IoT, which dynamically manages and adapts the study of ENADE's questions accordingly to the answered questionnaire. Any content that is available on the Internet can be from an IoT element, either physical or virtual. Therefore, it was created a system that provides pre-selected ENADE questions, in a synchronized way, for a group of students and, whenever they reached an average lower than the national one, other similar questions were provided with the explanation of the answer, allowing the student to achieve more familiarity with the ENADE's questions.

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1. Introduction

The teaching-learning system is an ongoing process that demands commitment and dedication from both the educator and the student. For this process to be as successful as it can be, it is important to use modern and more attractive tools that can facilitate the understanding of the content that is needed for the training and assessment of the student's performance.

The Exame Nacional de Desempenho dos Estudantes (National Student Performance Exam – ENADE), estimates the performance of students of undergraduate courses through evaluative materials that are developed by the Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira (National Institute for Educational Studies and Research Anísio Teixeira - INEP), which belongs to the Ministério da Educação (Ministry of Education - MEC). According to the INEP (2019), ENADE evaluates the undergraduate's performance regarding the course's syllabus and the abilities and competences acquired during their education. The exam is obligatory and the student's regularity must be included in their transcripts (INEP, 2019). Oliveira and Silva (2018) affirm that student performance is one of the factors associated to the success of the teaching-learning process, emphasizing the importance of verifying which are the influences on the formation of a diagnosis on the conditions that are faced in teaching environments. ENADE is an exam that is applied on paper and pen. According to the public notice number 40 of 2018, item 16.8, "The answers of the objective test and the discursive test should be transcribed with a black ink ballpoint pen, made of transparent material, on the Response Cards". Among the possibilities for studies regarding the ENADE exam, the investigation of viable alternatives for the administration and reduction of the test are particularly interesting as they tend to reduce cost, streamline the process and make evaluations more reliable. In this context, computerized tests acquire relevance, since they allow a reduced assessment and are able to estimate the students' skills. According to Santana et al. (2017), the reduction is possible by adapting the questionnaire through Computerized Adaptive Tests (CAT).

The CATs are administered through computational devices. In the present research, the items were presented as questions, which were adapted to the group that was answering the test, seeking to find a suitable questionnaire, resulting in a test with few questions as possible according to the group's average knowledge. For this, it was necessary to estimate the proficiency of the individuals in a synchronized way, to then have the group's average and therefore select the items that efficiently measured the proficiency of the examined group. According to Costa (2009), the basic notion of an adaptive test is to automatically mimic what an examiner would do, for the CAT is intended to manage items from a pre-calibrated bank that satisfies the examinee's level of ability. According to Santana et al. (2017), CAT items are chosen according to the Item Response Theory (IRT) model, which is adopted to describe the individual's response behavior.

Lopes et al. (2108), cite the use of Internet of Things (IoT) devices as an opportunity to adopt such apparatuses with the purpose of making classrooms increasingly intelligent and ubiquitous, close to the definition of a Smart Classroom.

For this article, a software that considered the assumptions of the AdaptThing computational model was created. It was responsible for dynamically adapting the operational behavior of IoT elements based on their contextual history in order to manage the CAT questionnaire considering the IRT applied to the group. The computational devices used to answer the questionnaire were considered as virtual IoT devices.

For a better understanding of this articles contributions, it was divided in sections. Section 2 presents the methodology. Section 3 demonstrates other articles that relate to what is proposed in the present work. Section 4 presents the AdaptThing computational model, its features and functionalities. Section 5 presents the performed study. Section 6 offers this work's conclusion. Section 7 presents the references.

2. Methodology

For the development of this work a structured methodology was adopted. It that was divided in the following phases: the analysis of related works, software tool development, software validation, field research and results evaluation.

For the analysis of related works, a wide search was performed using the Google Scholar databases through the keywords “ENADE”, “adaptive”, “dynamic”, “questionnaire”, “personalized”, “CAT” and “IRT”. Based on the results that were obtained in the search process, an in-depth research process was performed, which listed the works related to the proposed objectives of this article. The selected papers are described in section 3.

The development of the frontend software tool followed the specifications of the AdaptThing computational model described in Section 4. Therefore, a multiplatform software based on framework webview HTML 5 (Vilete, 2018) was generated, accessible by any device and, each instance execution was contemplated, therefore the responses of each participant were considered as values obtained by an IoT virtual device.

The default software was programmed to provide 6 ENADE questions on specific subjects regarding the subjects of operating systems, parallel and distributed programming, and core software. Whenever the class average was lower than the national ENADE average regarding the answer of the generated questionnaire, the software provided other similar questions to deepen the subject matter. Regardless of whether the questions were right or wrong, the software provided feedback on why that was the answer, thus assisting in the learning process. The backend software was implemented to demonstrate the capabilities of the AdaptThing computational model, which monitors and manages different elements of IoT - in this case the questions that were answered by the students.

The software was validated by applying it to two groups of students - one with 15 and the other with 23 members. 24 questions of various subjects were created through searches on various subjects, and 6 key questions were selected, simulating ENADE questions. For each of the "key" questions, 3 other complementary questions were chosen. Regarding the average grade - the equivalent of the national mean - random values were assigned between 4 and 9. This value was modified between the first and second validation group, for there was a need for adjustments, especially concerning the process of releasing questions synchronously, for the next question could only be presented once all the subjects had answered the current question.

For the field research, the adaptive software was applied to a group of 22 IT students who had already attended the operating systems, basic software and final phase of the parallel and distributed programming disciplines. The software aimed to get the class answers and adapt the questionnaire, providing other questions of similar subject matter, with three purposes: the first was to obtain subsidies to measure the average knowledge of the class, the second was to direct the complementary questions, and, the third, to allow the students more familiarity with the structure of ENADE's questions, allowing them to deepen their knowledge.

The evaluation of the results occurred after the data was collected through the questionnaire provided by the adaptive management software. The data was sampled and, later, graphs were produced to understand the obtained results. The study and the results achieved are presented in section 5.

3. Related works

The process of collecting scientific and academic works was restricted to publications in Portuguese that were freely available for download, found through the Google Scholar search engine. The process was

divided into two parts: first a wide search, identifying the already produced materials by other authors and then an in-depth search, analyzing their contents. After this in-depth search, 3 works were selected.
Among the works that were thoroughly analyzed, the most similar proposal to the present one was Santana et. al's (2017) article. Yoshioka, Teixeira and Ishitani's (2016) work has the most similar characteristics, while Pascoal et. al's (2016) article was chosen for using correlated concepts and applications. Section 3.4 presents a table comparing the afore mentioned works.

3.1 Work 1

Santana et. al's (2017) study aims to present data from a law school ENADE assessment. In the presented proposal, two multiple choice measuring instruments were used. One of the instruments was paper and pencil and the other was adjusted to the computer model, in an adaptive structure in the MOODLE environment.
The Adaptive Quiz plugin was used, which was adjusted to the questionnaires and available to the respondents. An algorithm was used to estimate the participant's ability, selecting questions based on a number of mistakes – grading the questions from the easiest to the hardest.
According to the authors, the level for the first question is parameterized, as for the others, an algorithm selects the next difficulty level or moves backwards depending if the answer was right or wrong. At the beginning of an attempt, the set of questions is undetermined. The number of questions that will be presented in each questionnaire is between the minimum and maximum determined in the parameters.

3.2 Work 2

Yoshioka, Teixeira and Ishitani's (2016) work is a case study where a question selection methodology is described, generating an a-Stratified Adaptive Test applied in two computer network classes, using a Computerized Adaptive Test (CAT), which was tailored to the user's knowledge. According to the authors, a common way to implement a CAT is to apply the Item Response Theory (TRI).
The execution of the questions followed an a-stratified adaptive method. Therefore, initially, the student randomly received a very easy question. In the case of success, they would randomly receive a question from the next level, otherwise remained at the same level, until completing 5 questions.

3.3 Work 3

Pascoal et. al's (2016) article presents a proposal for the development of an educational tool that aims to assist the student in the software engineering discipline, considering the real context in which learning occurs.
The development of an intelligent agent and its insertion into Moodle provides an oriented feedback regarding the student's level of knowledge and performance. Initially, a student knowledge module is executed, which aims to identify the Moodle environment software engineering student's background. The article uses ENADE's questions as guides to adapt the functioning of a chatterbot that answers questions about certain subjects.

3.4 Comparison between works

Table 1 presents the comparison between the analyzed works, highlighting their main characteristics in relation to the present article.

Table 1. Evaluated works and the observed characteristics.

Evaluated work / Observed characteristics	Work 1 (section 3.1)	Work 2 (section 3.2)	Work 3 (section 3.3)	Author's work
Adapts the questionnaire based on the individuals' knowledge	x	x		
Adapts the questionnaire considering the class' knowledge				x
Provides questions by category (easy, medium, hard)	x	x	x	x
Addresses questions based on historical criteria			x	x
Number of questions based on right and wrong choices	x	x		x
Provides a feedback to the students		x		x
Provides complementary questions to broaden the knowledge		x		x
Uses Moodle to make resources available	x		x	

Evaluated characteristics.

The biggest differential of this work compared to the other articles that were analyzed is due to the fact that it considers the average knowledge of the class/group of students instead of the individual knowledge, since other factors and characteristics used are very similar to those presented in the mentioned researches.

4. The AdaptThing Computational Model

The AdaptThing Computational Model is IoT with adaptive functionalities, whose main function is to manage IoT elements, whether physical or virtual, dynamically adapting its operational behavior (functionalities) according to the values that were obtained through context history analysis, allied to the arrival of new events along with temporal events.

The implementation of the model uses a centralized database with a distributed structure, for a single device cannot analyze the context as a whole, but with a set of devices, it is possible to analyze the scenario more broadly, enabling better decision making as well as a better understanding of what is happening at any given time.

The possibility to dynamically adapt operating parameters of a device enables greater energy savings during idle times, more effective information gathering given the context's needs, as well as the possibility to reallocate mobile resources to places where more detailed and accurate information is required.

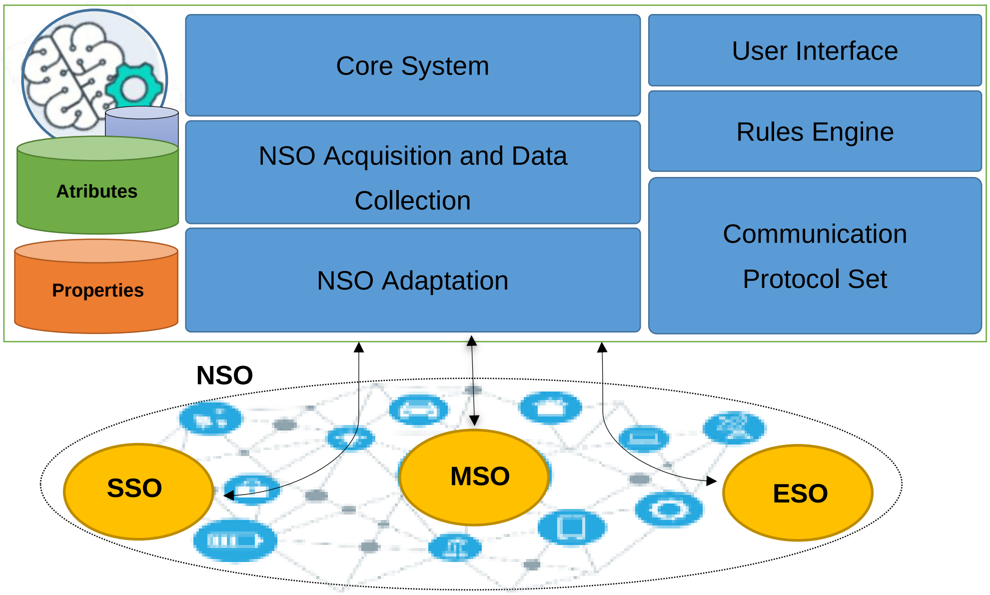


Figure 1. Overview of an AdaptThing computational model.

According to Figure 1, the computational model can operate three sensing categories, which are the following:

- Mobile Sensing Objects (MSO): composed of mobile sensory devices - sensor's that have their location changed over time -, such as smartphones, robots, drones, among others;
- Static Sensing Objects (SSO): composed of fixed (static) sensory devices - their location does not vary over time – such as, temperature sensors, humidity sensors, presence, radiation, among others;
- External Sensing Objects (ESO): composed of service providers, may physically be out of context, but provide important data from the outside world, such as weather data services, satellite imagery, among others.

These three sensing categories form a sensory network - the Network Sensing Objects (NSO) - which is formed by any type of device that can have its data computationally collected or acquired. Each individual device is called a Sensing Object (SO). A SO can be a smartphone, tablet, an embedded circuit with a microcontroller combined with several sensors, a computer running one or several services, among other IoT possibilities.

The AdaptThing model also has a rule machine-based inference process that is responsible for adapting the behavior of the NSO's Sensing Objects (SOs). The rule machine is always functioning, however it has triggers that signalize whenever new data arrives from the NSO, or if a consolidating temporal data event occurs. The model is also made up of two distinct database structures, responsible for generating two context histories.

- Attributes: Formed by any and all information that may be made available by the SOs. Used to form the data history of each SO. They are composed of values such as temperature, humidity, location, current, lighting, speed, situation, among others. If the content is non-numeric, post-processing or categorization is required;

- Properties: formed by the SO's configuration parameters. Forms contextual history about the behavior of each SO element. They are composed of values such as read rate, location, limits, and other fundamental information that are motive for this parameter' alterations – for the first motivation is activation, with its standard operational functionality parameters.

The user interface is a web application with a dashboard that displays the SO's data. This information is based on data consolidation and pre-processing, along with the management options of elements that belong to the NSO. The adaptation process, once triggered, alters the functional behaviour of the SO by modifying its operational parameters. Each SO can have completely different functions, such as sample rate, transmission interval, geographic destination, limits, among other possibilities.

As presented in this section, the AdaptThing is a computational model and not a software. However, it is a model that may be suitable for any application that involves IoT. Therefore, two softwares were developed: one for SO management and one for its provision.

The software that manages the SOs needs to analyse context - the group data - to arrive at a comparison measure linked to "history" - which in this case is the national average of ENADE. For this it was necessary to manage the access and release of questions in a synchronized way, similar to reading data from a sensor set. At first, the software waits for a while to know which elements - in this case the students that will be part of the group. After this procedure, it always waits for the student's response. There is a feature in the software that ignores the participant if they cannot communicate with them or go beyond a predefined time. The conduction of the answers derives from the group average evaluation, although the data of each member is stored.

For the user application, a multiplatform software was created, where the questions were answered synchronously, always waiting for the next step, started by the construction of the group and successively the application of the questionnaire.

5. Proposed study

The purpose of the present article was to provide a group of students with ENADE questions in a dynamic and adaptive way according to the average of their knowledge. It was sought to familiarize students with the structure of ENADE's questions and, through the analysis of the answers, suggest complementary questions to improve the subject's understanding. To achieve these objectives, a software was developed considering the premises of the AdaptThing computational model, where a set of questions was synchronously provided.

Table 2 shows the origin of the ENADE questions, the graduation students' national average, which was obtained from the Relatório INEP de Desempenho de Cursos (INEP Course Performance Report) that are made available to the Instituições de Ensino Superior (Higher Education Institutions). The average that was achieved by the group of students that answered the questionnaire is also presented. The questions were taken from previously conducted tests on 3 subjects: operating systems, parallel and distributed programming and basic software. Once the questions were chosen, the presentation order was random, but the whole group answered each question synchronously.

Table 2. Origin of ENADE questions and performance average.

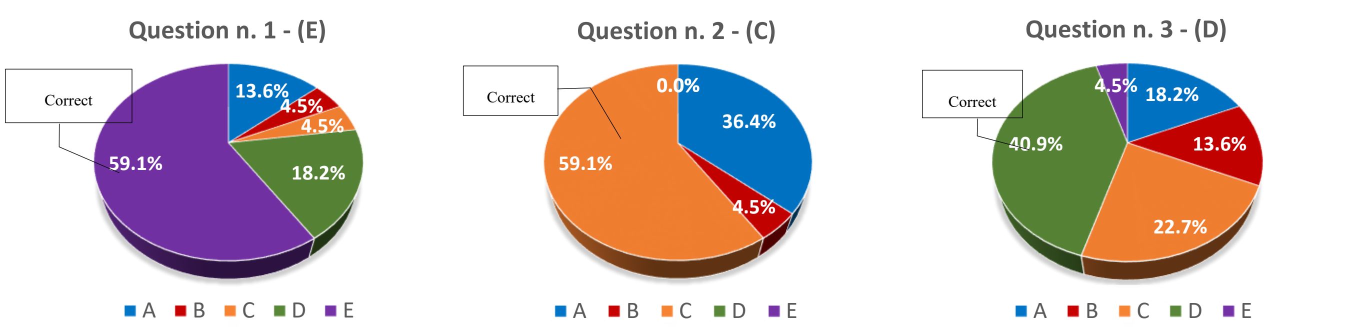
	ENADE Questions Specific Component: Objectives	Year	Num.	National average	Class average
Q1	Computer Science - Bachelor Degree	2017	31	33,3 %	59,1 %
Q2	Computer Engineering	2017	22	52,5 %	59,9 %
Q3	Computer Science - Information Systems – Bachelor Degree	2005	22	23,5 %	40,9 %
Q4	*Computing - Computer Science - Computer Engineering*	*2005*	*41*	**90,0 %*	*36,4 %*
Q5	Computing - Computer Science - Computer Engineering	2005	42	34,5 %	36,4 %
Q6	Computer Science - Bachelor Degree	*2017*	*35*	*31,0 %*	*22,7 %*

Origin questions.

The question identified as “Q2” (number 41 of the 2005’s exam) presented in Table 2 was, for some reason, disregarded in the ENADE exam. Therefore, for the sole purpose of forcing the presentation of complementary questions, its national average was set at 90.0%. Figure 2 presents the results that were obtained by applying the ENADE questions to the study group. As can be observed, there is a scattering in chosen alternatives, indicating doubts, ignorance or concept confusion. Another marked detail is that there is a rounding in the first decimal place of the graphs, allowing non-formation of the complete 100% in the sum of the presented values.

In the experiment, a total of 6 ENADE questions and 6 additional questions were presented, for in the Q4 and Q6 questions, the group obtained an average lower than the national one. The average time measured for each question was 4.2 minutes for both the ENADE and complementary questions.

The next question was presented as soon as the last student finished answering the current one. The system verified the group average and, given the comparison with the historical value - in this case the national average -, a new ENADE question or 3 additional questions were presented.



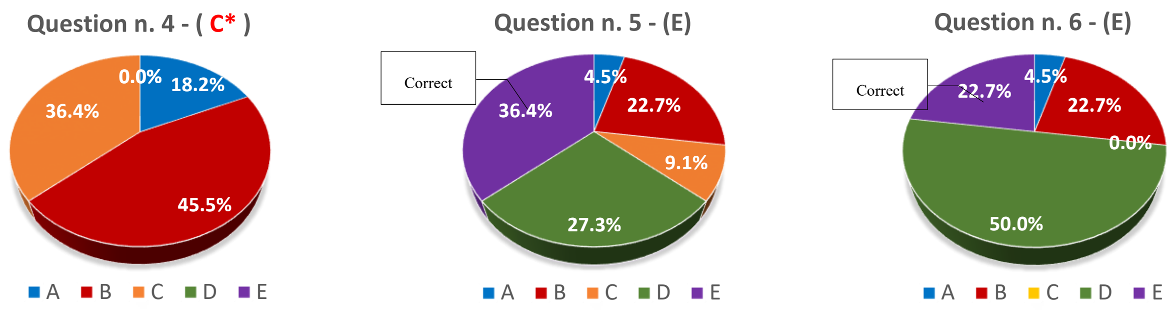


Figure 2. Results obtained by the class in the ENADE questions.

6. Conclusion

This work presented the application of an educational software, which follows the specifications of the AdaptThing computational model, that allows to dynamically adapt the operational behavior of IoT elements, whether physical or virtual.

The purpose of the application was to provide ENADE questions to a group of students in a synchronized manner, considering the answers as values obtained from IoT virtual elements. The software waited for the response of all students to a given question, only releasing the next after all of them answered the current one. For each solved question, the results were compared with the ENADE's national average - the already known historical values. Whenever the national average was higher than the class' average, three more questions of similar subjects were offered in order to enhance the understanding on the subject. Regardless of whether the student gets the questions right or wrong, whether the ENADE's or the supplementary questions, feedback has always been provided explaining the fundaments of the right answers and the wrong questions.

The software adapts the test according to the class average, aiming to not repeat a certain type of question that is statistically well understood, or at least has a statistical understanding that is higher than the national average. Future works may explore the possibilities related to the wrong answers, however, because the software offers feedback, there were no further evaluations on the distribution of the mistakes.

The students considered the logic of the software as a way to avoid the repetition of questions which had its subject already comprehended by the majority of the class (supposedly). Another positive point that has been highlighted is the ability to resolve the questions with any type of device that had Internet connectivity, however most preferred to use a computer, especially due to the images in the questions.

The AdaptThing computational model is considered to be generic enough to be applied to different performance scenarios, including the education scenario. The present application considered the respondents' data as IoT objects, adapting the questionnaires, as it would adapt the operation of any device, whether physical or virtual. The results of the produced software can be used for the graduation students or even for higher education subjects as an auxiliary tool for familiarity with the ENADE question structure, and the capacity to allow for the students' better understanding of the subjects, given the feedback after each question.

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