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How to provide intelligent assistance to learners in e-learning environments?

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Abstract: The health consequences caused by the spread of the COVID-19 disease have motivated many countries to turn to e-learning environments. This technological solution is the only one that has allowed the continuity of the educational process. Unfortunately, this widespread teaching mode also poses multiple problems that may negatively affect the learning process, including the autonomy of learners, the lack of interaction and collaboration between them, the lack of feedback on their activities, and the lack of appropriate support for learners with difficulties. Solutions to these challenges include personalising educational content and providing personalised and adapted assistance. Providing help and support to learners can decrease some of the harmful effects of the previously mentioned problems. The present work falls within this context and aims to propose an approach that uses the traces left by learners to

detect those who have difficulties and provides them with adequate assistance. An online learning system called SANED adopted the proposed approach. To validate the proposed ideas, real students tested the proposed tools. Found results are encouraging and very promising.

Keywords: intelligent assistance; adapted assistance; traces; indicators; learning difficulties; learning environment.

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1 Introduction

In our daily lives, we all, without exception, rely on others to assist us in completing one task or another. Whether doing simple or more complex and strenuous activities, asking for help or helping others is essential. Several factors, such as pressure, load, and personal or health issues, could place the learner in various states of difficulty regardless of his intelligence level. Among these difficulties, the lack of understanding is the most harmful, causing him to fail or drop out. To avoid that fate, the learner may seek assistance from those around him, such as his teachers, peers, or others. He would use all available means, especially effective and quick ones, such as asking for information, enrolling in special courses, or buying books.

However, some students cannot express themselves or declare their problems due to shyness or communication issues. As a result, teachers, parents, and even administrators should identify those in need and provide adequate assistance. Although the primary goal of e-learning is to overcome the disadvantages of face-to-face learning, learners also face

several complications. In addition to the difficulties mentioned above, they must overcome additional obstacles imposed by this mode of instruction, such as the lack of physical communication, technical problems, difficulty using the system, inertia, autonomy, and many others. When developing such systems, choosing an intelligent e-Learning system that can identify learners in difficulty, detect the type of difficulty as accurately as possible, and then propose an appropriate solution is a critical strategy.

Several research studies have been conducted, resulting in the development of numerous systems (Casamayor et al., 2009; Ginon et al., 2016; Grivokostopoulou et al., 2013; Mavrikis et al., 2016; Huang et al., 2010; Rosselle, 2012; Santos et al., 2015; Thai, 2016). Nevertheless, some concerns about these systems' limitations have been addressed after a period of use. Some of them are the following:

- Users of these platforms complain about the lack of interactivity and motivation among learners.
- Even though these systems tell teachers which learners are struggling, it remains up to them to find the solution.
- Pedagogical difficulties are the only type dealt with, while learners need different types of assistance (technical, pedagogical, etc.).
- The help or assistance tools offered by these platforms are insufficient as they only offer advice and remarks in textual form.
- These systems do not consider the questions and requests made by learners.

Through this work, we attempt to address some of the learners' concerns and inquiries to improve online learning quality. The goal is to implement a system that supports the learning, assessment, and communication processes by incorporating an intelligent assistance tool that identifies learners with difficulty while performing these various processes. The proposed tool accurately determines the difficulty and suggests simple and effective solutions. It also provides learners with additional tools to express their problems directly. To achieve this goal, several research questions are posed and need answers, including:

- How to identify learners who need online support?
- What tools should be adopted to ensure adequate support to meet the learners' expectations?
- How to deal with all the learners' questions and queries during an e-learning session?
- Finally, how can we measure these techniques' contribution and impact on the levels of learners in these computer environments dedicated to human distance learning?

This paper is organised as follows. Section 2 presents a literature review on learning difficulties faced by learners and the up-to-date available support tools. The proposed approach is described in Section 3. Section 4 presents the experiment carried out in the computer science department, as well as the results and the surrounding discussion. Finally, the general conclusion, the work limitations, and future work are highlighted in Section 5.

2 Literature review

2.1 Need for learners' support in e-learning environments

Many technological developments have been made in several fields to make our lives easier. In education, for example, we have moved to online teaching, where learners can study at their pace and time and without writing a word. The same goes for the teachers who perform their job with less burden, stress, and effort. This mode started to replace face-to-face instruction gradually. However, online learning has various limitations like autonomy, inertia, lack of motivation, low interaction, technical issues, and many others, causing learners to struggle and pushing them to fail or give up. Being in difficulty means being unable to achieve or perform assigned tasks correctly. In the educational field, this occurs when a student encounters difficulties that prevent him from progressing in his studies following the objectives of the training program (Adam et al., 2017; Gosselin et al., 2003) or students who demonstrate low levels of interest in their learning in terms of conduct, emotion, and cognition (Yang, 2021).

These difficulties causes may vary; some are temporary, while others persist throughout the learner's learning journey. Most of the time, they are expressed by the interaction of various causes, including technical causes (Ali et al., 2018; Gülbahar et al., 2010; Gutiérrez-Santiuste et al., 2016; Ramadiani et al., 2016), cognitive and mental causes (Ali et al., 2018; Lafifi et al., 2010; Muhammad et al., 2015), and personal causes (Schott et al., 2003). Some e-learning systems are designed to provide learners with support alongside standard learning services (Saleh, 2020). Others specialise in assisting struggling learners by providing level-improvement services (Choudhury, 2020; Szulc, 2019).

2.1.1 E-Learning systems offering remote assistance

Several e-learning researchers invested in developing various systems to assist struggling learners. Following is a list of research studies focusing on the development of such systems:

2.1.1.1 Systems for educational support

The teacher's method for preparing and presenting educational content is controversial. As a result, several types of assistance tools software (ATS) have been created. Rosselle has implemented a teacher module (TM) that collects information about the teacher and his teaching environment. This data is used by the ATS to customise the device to the teaching context and the teacher's preferences and needs. The TM manages data using inference rules applied to ontology (Rosselle, 2012). Thai presented an instructional guidance model to enhance SEPIA (Specification and Execution of Personalised Intelligent Assistance). This model extends the aLDEAS (a Language to define epi-assistance systems) language by defining the different types of instructional guidance: sequential, contextual, temporal, personal, and free. The SEPIA engine interprets these types of guidance by translating them into aLDEAS rules (Thai, 2016). Mavrikis and his colleagues have created a set of visualisation and notification tools for the MiGen system called teacher assistance (TA). The goal is to assist teachers in focusing their attention on all students and intervening more effectively. The learning awareness tools user

experience (LATUX) approach was used to develop these tools (Mavrikis et al., 2016). Grivokostopoulou and his team also present two other tools that help instructors teach logic formula conversion using an interactive web-based system. The first, the tutoring manager (TM), assists the teacher in managing the didactic material, monitors the learners' progress, and identifies any difficulties they may encounter. The second tool is the difficulty estimation intelligent system (DEIS), which assists him in determining the difficulty level of a formula conversion process (Grivokostopoulou et al., 2013). Santos and his research group use fuzzy logic to create eTutor, a web-based assisted learning tool. It examines and reports to the teacher the learner's learning behaviour (Santos et al., 2015). Corredor and Gesa have proposed a personalised support tool for dyslexic students. It was incorporated into a learning management system (LMS). This tool detects reading preferences and difficulties before recommending interventions based on specific cognitive deficits (Corredor and Gesa, 2012).

Some works have investigated collaboration in the context of assistance. Ospina and Fougères proposed a multi-assistance system based on a multi-agent system (MAS) integrated into an iPedagogical learning environment. This system is intended to facilitate a wide range of collaborative activities, particularly project management, by providing an ergonomic and intelligent set of assistance and advice to all users (Ospina and Fougères, 2003). Casamayor and colleagues presented an intelligent interface agent capable of assisting the teacher in supervising and detecting difficulties in collaborative activities. This data is derived from the indicators gathered about each learner's interaction with the system, which is created using the web usage mining (WUM) technique (Casamayor et al., 2009).

2.1.1.2 Systems dedicated to technical assistance

In the literature, few works have addressed this type of assistance, and the only systems found are those of generic advisors. The generic assistant aLDEAS (Ginon et al., 2016) is made up of an event detector that monitors the target application and notifies the generic assistant of any occurred events; this determines when an assistance action should be launched. Table 1 provides a general summary of the works presented above.

The study of the work and the tools developed enabled us to identify some limitations, including:

- Almost all authors have developed systems that favour the teacher over the learner, who is the primary actor in the e-learning field
- They focused more on a specific type of difficulty, which is learning.
- They deliver assistance in the form of information about struggling learners rather than a solution to the difficulty itself.
- They provide textual advice as assistance.

These distance learning platforms' complexity and their often-crowded interfaces pose significant usability challenges. Users, mainly those unfamiliar with computer tools usage, may become overwhelmed and quickly abandon their use. Aside from technical difficulties, there are those imposed by the online teaching mode, such as autonomy, lack of interaction, and inertia. There are also difficulties imposed by each learner's personality and abilities.

Table 1 Summary table of related works

Author year	*Developed system*	*Goals*	*Targeted difficulties*	*Assistance type*	*Used approach*	*Target actors*
Thai (2016)	SEPIA system upgrade	Select relevantly learning activities and offer them to learners	Pedagogical	Automatic	aLDEAS (a language to define Epi assistance systems)	Learner
Ospina and Fougères (2003)	Multi-Assistance Systems integrated With the iPedagogical	Facilitate the use of cooperative activities, especially for project management activity	Cooperation	Automatic	Multi-agent system	Learner teacher administrator
Ginon and al. (2016)	aLDEAS	Provide the user with technical assistance according to his profile and the context of the application	Technical	Automatic	If conditions then assistance actions. Type of assistance rules	//
Casamayor et al. (2009)	Intelligent interface agent	Provide the teacher with information on the learner's progress and type of participation	Group work	Semi-automatic	Web usage mining (WUM)	Teacher
Rosselle (2012)	Module Teacher integrated in an ATS	To guide teachers in their work	Pedagogical	Automatic	Inference rules applied to ontology	Teacher
Mavrikis and al. (2016)	Teacher Assistance (TA) integrated with the MiGen system	Helping teachers to focus their attention on all learners for better intervention	Pedagogical	Automatic	LATUX (Learning awareness tools user eXperience)	Teacher
Grivokostopoulou and al. (2013)	FOLtoCF conversion system	Helping teachers teach the conversion of logic formulas	Pedagogical	Automatic	//	Teacher
Santos et al. (2015)	A web-based assisted learning tool called eTutor	Monitors and reports the student 's learning behaviour to the teacher	Pedagogical	Automatic	Fuzzy logic analyses the Interactive Learning Objects status to trigger preconfigured actions.	Teacher
Corredor and Gesa (2012)	//	Assisting dyslexic students	Pedagogical	Automatic	//	Learner

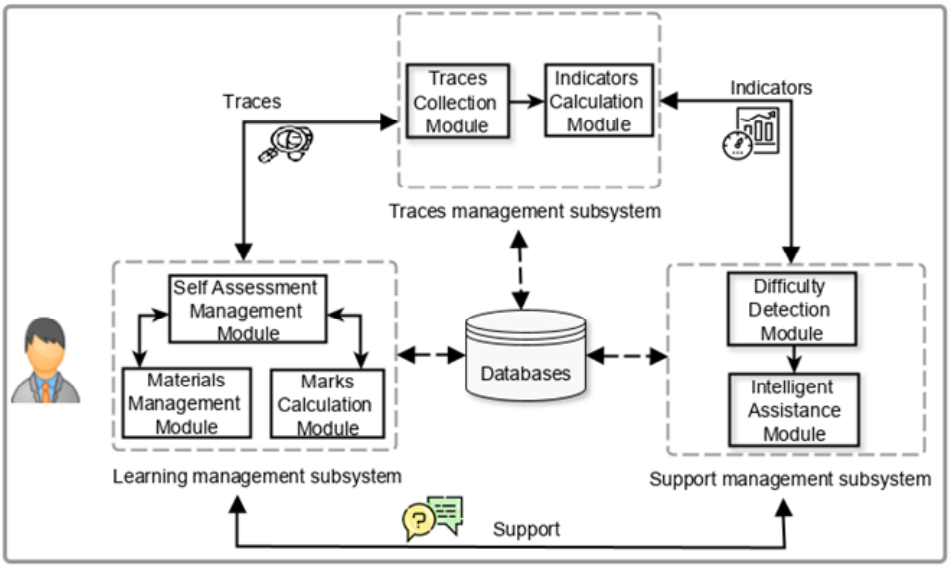
This work aims to create an assistance tool that assists users of an e-learning platform. The assistance is primarily for the learner and can be related to any difficulty. Furthermore, it can take various forms, such as messages, videos, and sounds. The following Section discusses the design we propose for such a tool.

3 A new approach for intelligent assistance of learners in an e-learning environment

The main objective of this research is to detect learners experiencing difficulties and provide them with adequate and timely assistance to avoid failure and overload. The proposed approach should meet the following objectives:

- Providing two types of student support: implicit and explicit.
- Different types of assistance exist depending on the difficulty detected in the student's profile and preferences.
- Engaging teachers and administrators in supporting learners and responding to support requests and frequently asked questions (FAQs).
- Providing teachers with feedback so they can intervene and advise learners who show difficulties based on their assessment results.
- Providing users with a system to evaluate assistants and helpers and classify them under the headings top assistants and top helpers.

Figure 1 General architecture of SANED system (see online version for colours)



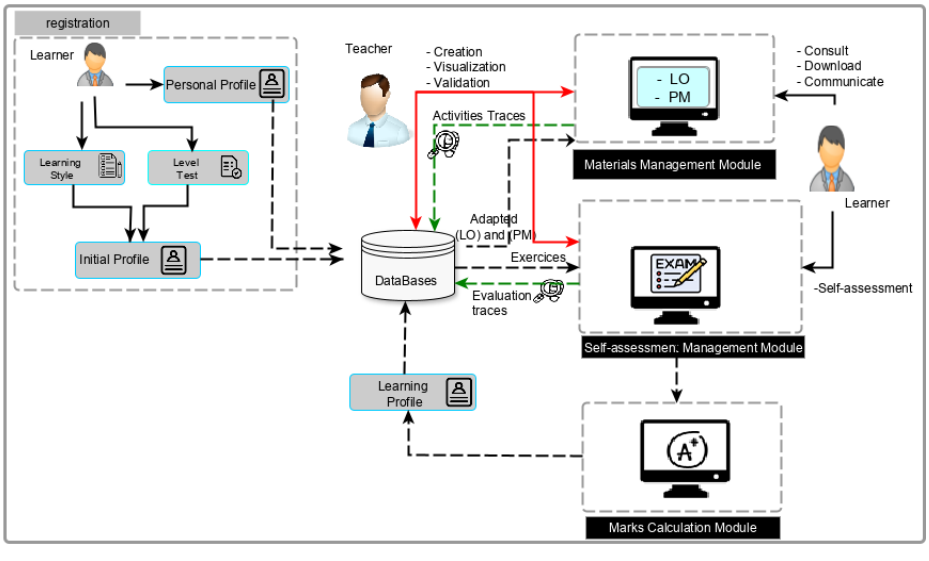
An online human learning system supported the proposed approach. The system is named SANED, which was hijacked from the Arabic word having the same sense, which means

support or backing. As shown in Figure 1, it comprises three subsystems. A subsystem specialised in learning that provides teachers and learners alike with the necessary tools to manage learning objects and assessment tools. The second subsystem collects information regarding the different activities and traces of the learners (trace management). It then provides the third subsystem with the necessary data to deduce the learners in difficulties and propose adequate assistance (assistance management).

3.1 Learning management subsystem

This subsystem (Figure 2) manages the learning operations. It is composed of the following three modules:

Figure 2 Functional architecture of the learning management subsystem (see online version for colours)



3.1.1 Materials management module

SANED system provides the teacher with tools to organise the learning objects (LOs) in a hierarchical form using the principle of prerequisites to allow him to condition the passage from one LO to another according to the complexity and pedagogical organisation of the subject. Similarly, for the pedagogical resources (PRs), their distribution is conditioned by the results of two tests linked to the learner's cognitive level and learning style.

As the learners progress through the learning process, their levels and preferences may change. For this reason, the proposed system reconstructs the new Cognitive Profile of learners and must check it before each display of the resources to adapt them to the state of each learner according to the following rules:

- If the cognitive profile is low: the system displays the PRs that require a low cognitive level.

- If the cognitive profile is medium: the system displays the PRs that require a medium cognitive level.
- If the cognitive profile is high: the system displays the PRs that require a high cognitive level

3.1.2 Self-assessment management module

A teacher can use this module to create one or more self-assessment exercises for various existing tests, namely:

- Subject level test (LT) that calculates the initial cognitive profile of a learner (basic/medium/high).
- The progression test (TP) is attached to the different learning objects (LOs) of the subject and allows the validation of the acquisition of the knowledge of the current LO by the learner to pass to the next LO.
- Final test (FT) declares the learner's final verdict on the subject, either 'pass' or 'fail.'

Each exercise proposed by our system is composed of questions of three types:

- Multiple-choice questions (MCQs) with a maximum of four choices.
- True/false questions.
- Direct questions with open and short answers.

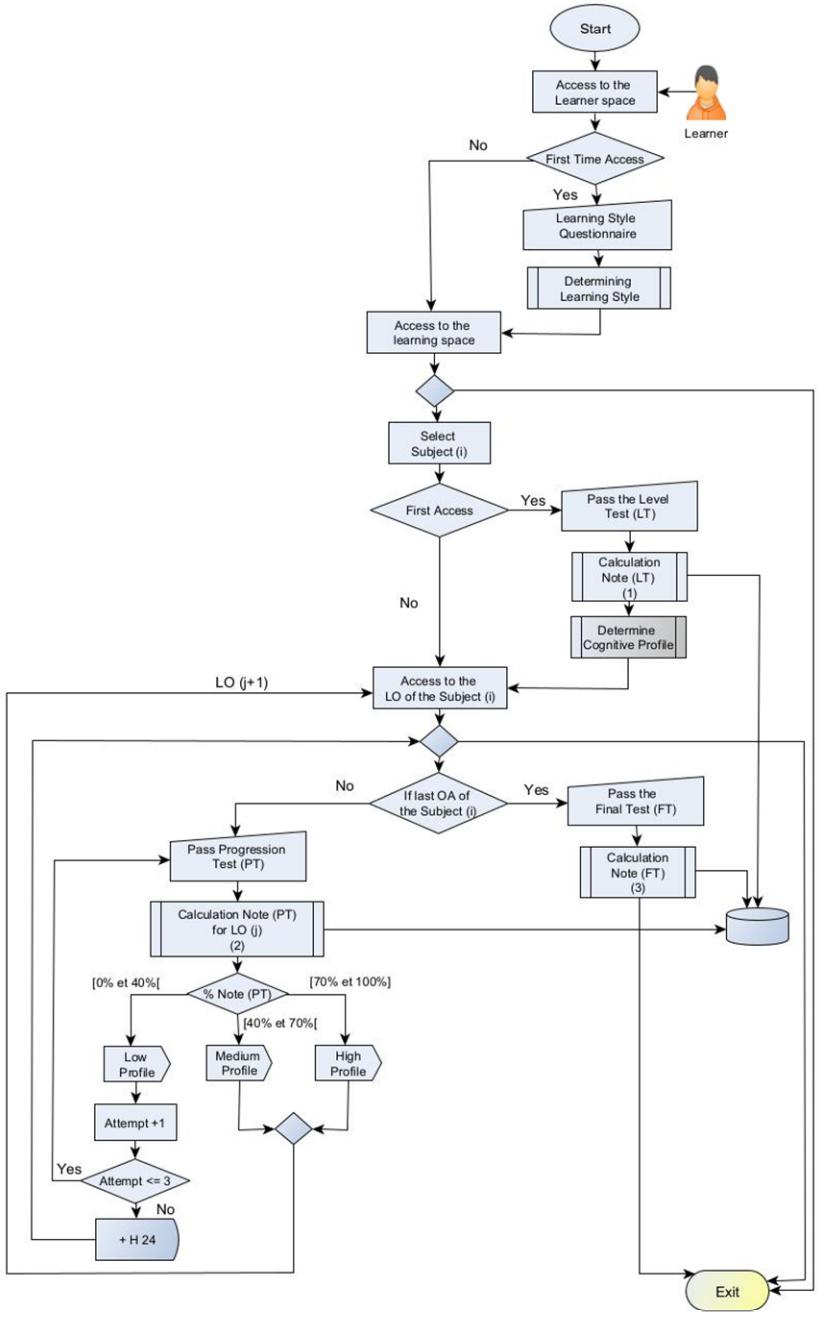
The following section provides more details on how the scores and percentages for the various tests were determined. The evaluation method for the various tests is depicted in Figure 3.

To progress to the next LO, the learner must successfully answer at least half of the questions on a self-assessment of a progression test (PT) type. If not, the test must be retaken; a maximum of three attempts is allowed. When all attempts are unsuccessful, the intelligent support module of the SANED system assists the learner, advising them to reread the current LO and retry the assessment. The system checks the dates and gives him 24 hours to prepare and retake the self-assessment. This process is repeated until the learner passes and moves on to the next LO. Determining the learner's cognitive profile allows the LMSS to display the appropriate PRs at the learner's level and the support management subsystems (SMSS) to determine if the learner is having difficulties if the self-assessment fails.

3.1.3 Marks calculation module

The teacher should prepare a set of exercises for each learning object to test the learners' knowledge acquisition level. Learners can self-assess themselves by answering various questions in the exercise. At this stage, the MCM module calculates the mark based on the criteria specified by the teacher while designing the exercises and applying the pre-established processing formulas to the learners' responses.

Figure 3 Self-assessment process in SANED (see online version for colours)



For a set of Subjects **M**, containing a set **L** of LOs and self-assessment tests containing **N** questions, the formulas for calculating the marks of the different tests are presented as follows:

a Calculation of the LT score for material K (LTS_k)

$$\mathbf{LTS_K} = \frac{\sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{notQ_{ik}}}{\sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{Qmax_{ik}}} \tag{1}$$

Percentage of the LT score for subject **k**:

$$\mathbf{PRL_k(\%) = LTS_k * 100}$$

notQ$_{ik}$ The learner's score for the question **i** in the subject level self-assessment **k**.

Qmax$_{ik}$ The maximum score of question **i** in a level self-assessment for subject **k**.

b Calculation of the LO progression test score **j** for the learning subject K (PTS_{jK})

$$\mathbf{PTS_{JK}} = \frac{\sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{notQ_{ij}}}{\sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{Qmax_{ij}}} \tag{2}$$

Percentage of the LO progress test score **j** for subject K:

$$\mathbf{PRP_{jk}}(\%) = \left[W_{LT} * \mathbf{LTS_k} + W_{PT} * \left(\sum_{\mathbf{i=1}}^{\mathbf{j}} \mathbf{PTS_{ik}} / \mathbf{j} \right) \right] \Big/ \left(W_{LT} + W_{PT} \right) * 100$$

notQ$_{ik}$ The learner's score for the question i in a self-assessment of the **LO**$_j$.

Qmax$_{ik}$ The maximum score for the question i in a self-assessment of the **LO**$_j$.

$\mathbf{W}_{LT}$ Coefficient of the LT

$\mathbf{W}_{PT}$ Coefficient of the progress test

c Calculation of the FT score of a subject K (FTS_k)

$$\boldsymbol{FTS_K} = \frac{\sum_{i=1}^{n} notQ_{ik}}{\sum_{i=1}^{n} Q\max_{ik}} \tag{3}$$

Percentage of the FT score of a learning subject K:

$$\mathbf{PR}\left(\mathbf{M_K}\right)(\%) = \left[\left(W_{LT} * \mathbf{LTS}_k + W_{PT} * \left(\sum_{j=1}^{l} \mathbf{PTS}_{jk} / \mathbf{l} \right) + W_{FT} * \mathbf{FTS}_k \right) \right] \Big/ \left(W_{LT} + W_{PT} + W_{FT} \right) * \mathbf{100}$$

notQik The learner's score for the question i in the FT self-assessment of subject K

Qmax$_{ik}$ The maximum score of question i in a FT self-assessment for subject k.

$\mathbf{W_{LT}}$ Coefficient of the LT

W_{PT} Coefficient of the progress test

W_{FT} Coefficient of the FT.

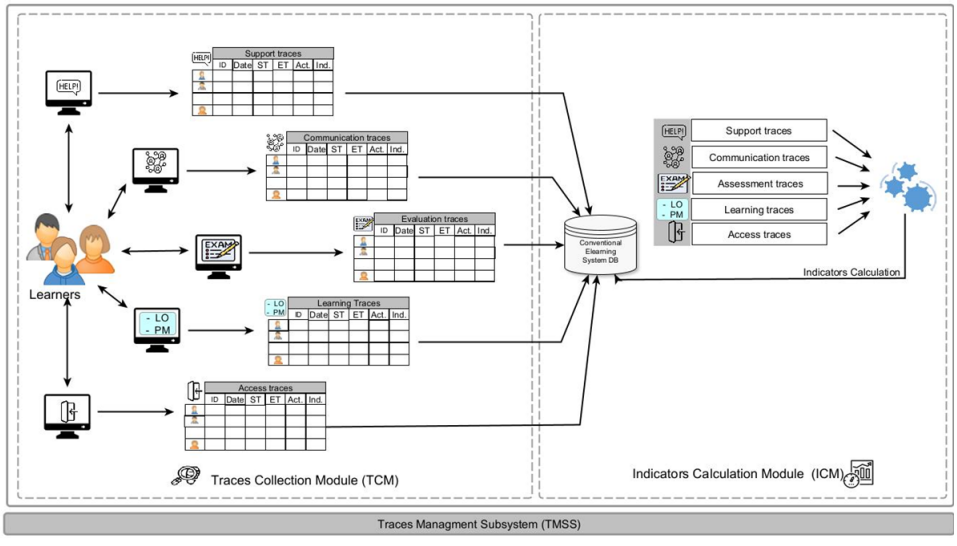
The learner's cognitive profile can be deduced from the percentage obtained as follows:

- If the percentage is in the range [0 %–40%] the cognitive profile is low.
- If the percentage is in the range [40%–70%], the cognitive profile is medium.
- If the percentage is in the range [70%–100%], the cognitive profile is high.

3.2 Trace management subsystem

This subsystem collects and processes the traces left by each learner (see Figure 4). Its primary role is to collect all learning traces left by the learner, like completed tasks, including the date and times at which they started and completed. After that, these traces are analysed using a set of rules to obtain a set of indicators.

Figure 4 Functional architecture of the traces management subsystem (see online version for colours)



The TMSS accomplishes these two tasks through the following modules

3.2.1 Traces collection module

Its task is to record every action the learner takes from the time he connects to the system until he disconnects. This data is known as traces and are analysed to determine the difficulties. These traces have been classified into five major types, which are as follows:

- Learning traces: These are the traces the learner leaves while engaging in learning activities. For example, while consulting learning objects or consulting and downloading learning resources.

- Evaluation traces: They are the traces left behind after completing self-evaluations. For example, while consulting the answer key.
- Access traces: they concern access to the system's various tools as well as the system itself. For instance, while accessing the FAQ, forum, and messaging.
- Communication traces: they consider using the platform's communication tools (messaging, forums). For example, while sending messages, posting topics, and replies.
- Support trace: the learner left these traces when he used the support tools (FAQ, support requests). For example, while asking questions and sending or responding to requests.

3.2.2 Indicator calculation module

This module applies calculation formulas to all the traces collected by the TCM to deduce indicators that may be used as benchmarks to make decisions on the learners' state and to identify those who are having difficulty. The rest of this section provides an example of indicators used by our system (Table 2). The remaining indicators are included in the appendix.

Table 2 Indicators related to access traces

Traces	*Indicators*	*Rules*	*Interpretation*
Access to the system	Dif_Date	Date of last access – date of current access > 3 days	Low rate of access to the system
	Nbr_Tan	Number of failed connection attempts > 3 times	High rate of connection failure
Access to communication tools (forum, messaging)	Nbr_CLC	Number of clicks on the Links of the Communication tools (Per week) < 3 times	Low use of communication tools
Access to support tools (FAQ, support request)	Nbr_CLA	Number of clicks on support tool links (Per week) < 3 times	Low demand for assistance

3.3 SMSS

SMSS is our most crucial subsystem; it detects difficulties and determines which assistance is essential. After the TMSS collects and analyses all the traces, the SMSS takes the resulting indicators as input, attempts to deduce the learner's difficulty, and proposes appropriate assistance. The two modules, DDM and IAM (mentioned below), do this automatically. If the learner finds that the proposed assistance is insufficient, he can consult another one or go himself to get it from his teachers, classmates, or system administrators by using the Request Assistance option managed by the module MGDEA. The Assistance Management Subsystem consists of three modules:

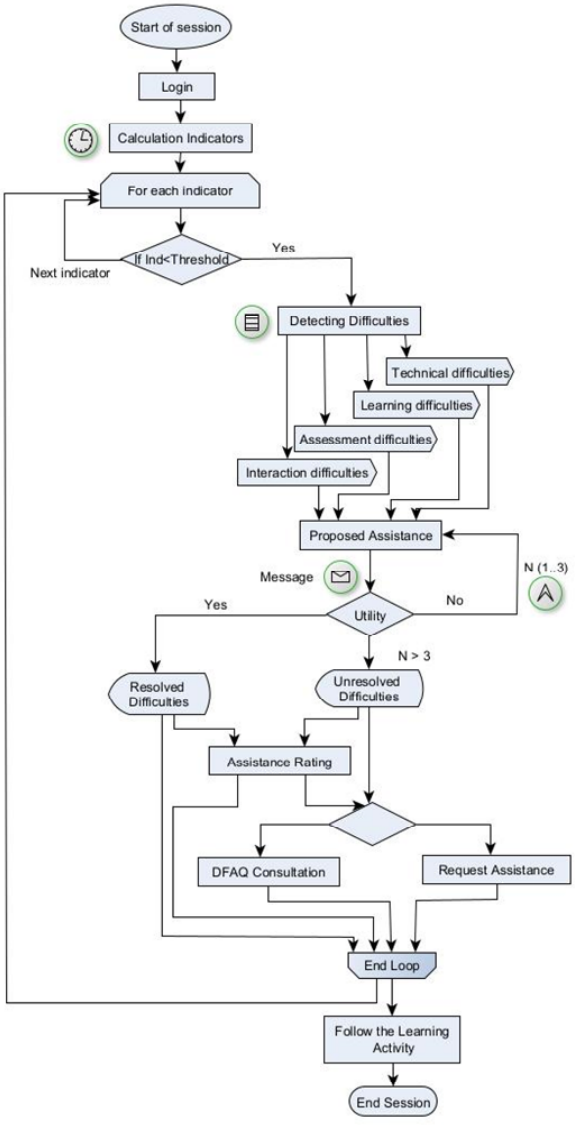
3.3.1 Difficulty detection module

Each indicator from the indicator calculation module (ICM) is associated with a specific type of difficulty. The function of the DDM module is to research and find this

equivalence, which is then used by the intelligent assistance module. Below, we define the types of difficulties found by our system:

- Technical difficulties: these are those related to access traces.
- Learning difficulties: these are related to learning activities.
- Evaluation difficulties: these difficulties take into consideration the traces related to evaluations.
- Interaction difficulties: these are related to the communication and assistance traces.

Figure 5 Support process



3.3.2 Intelligent assistance module

This module gets the difficulty identified by the DDM. The learner then receives three suggestions suitable for the level of difficulty. They are presented from the simplest to the most complex. If learners find the displayed proposal helpful, they may consider and evaluate it. If not, they may see it as useless, and the following proposal appears. This process continues repeating until the difficulty is deemed resolved or not. The assistance process is illustrated in Figure 5.

Table 3 presents the system's main assistance cases proposed to the learner.

Table 3 A few assistance cases provided by SANED

Traces	*Difficulties*	*Type of difficulties*		*Assistance offered*
Communication via messaging or via the forum	Difficulty in communicating with others (Language, expression difficulties, etc.)	• Interaction • Technical	1	Message asking to consult help
			2	Message offering copies of the friendly message
			3	Message offering the names of learners of the same age or sex
			4	Message with links to topics that may be of interest to them (corresponding to their learning style)
			5	Message proposing questions from the FAQ related to the problem
Use of educational resources	Difficulty in consulting, viewing or downloading a PR.	• Technical • Learning	1	Message with an illustrative video explaining how to access, view or download a resource
			2	Message offering to install the necessary software (adobe reader, office word, etc.)
	Difficulty in understanding the content of the resource		3	Message offering resources that require a lower cognitive level
			4	Message offering resources with different formats
Assessment of a LO or a subject	Difficulty in understanding the content of a subject	• Learning • Evaluation	1	Message suggesting contacting the teacher
			2	Message offering resources that require a lower cognitive level
			3	Message offering resources with different formats
			4	Message proposing Forum topics related to the content of the subject

3.3.3 Explicit assistance request management module

If learners find that none of the help provided by SANED is helpful, they may ask for assistance from a classmate or a teacher if it is a learning difficulty or from the administrator if it is a technical difficulty. They may do so by using one of the following two tools:

a Request for assistance section: This section is similar to a messaging system, where the learner can send a message explaining his problem to one of the system users. If one of the actors replies, the learner can evaluate the proposed assistance and comment on whether the actor is a good assistant or not. These evaluations allow displaying the list of top assistants and top assistance.

b Dynamic frequently asked questions (DFAQ) section: Learners can refer to the list of questions in the FAQs to find solutions to their issues. If no question seems to fit their situation, they can ask a new question in the 'subject FAQ' if it involves a learning or assessment difficulty or in the 'technical FAQ' if it involves a technical or interaction problem. The administrator or teacher in charge of the FAQ analyses the question and evaluates its relevance. If the question is found useful and has not yet been addressed, it is added to the FAQs. As more learners participate by sending questions, the FAQ keeps growing, and they may indeed find solutions to their requests. This dynamic evolution of the FAQ increases the motivation and interaction of all actors.

4 Experimentation

This experiment aims to study how the proposed adaptive assistance used by the SANED system has affected the learners' learning. The questionnaire method gathering the opinions of numerous students. It is based on assertions rather than observations. For this purpose, appears to be the most effective for the following inquiries (research question) should be addressed:

RQ 1 How do learners evaluate the usability and usefulness of SANED (as a technological product)?

RQ 2 How do learners feel about support in SANED?

4.1 Participants

This experiment was conducted with second-year undergraduate students from the computer science department studying the 'computing architecture' subject. 32 students took part in this experiment. During this experiment, we explained to students that during the learning process, the system would detect students with difficulties and give them feedback to help them adjust their learning. They received a quick explanation of SANED's operation and how to use it. It should be noted that the students are familiar with Moodle (see https://moodle.org/), the university's online learning tool. In this experiment, we attempted to answer the above questions.

Table 4 Questionnaire 1 on the question 'How do learners rate the usability and usefulness of SANED' and Total number of headcounts

Categories	*Factors*		*Closed questions*	*Strongly disagree*	*Disagree*	*Neither agree nor disagree*	*Agree*	*Strongly agree*	*Total*
Usability	Learning	Q1	SANED is a tool that was easy for me to learn how to use through an introductory training course	0	2	0	19	11	32
	Facility	Q2	SANED is a tool that I found easy to use (no complexity)	0	0	2	12	18	32
	Clarity	Q3	SANED is a tool with which interaction is clear and understandable (easy menu, command, and message)	1	1	1	19	10	32
	Controllability	Q4	SANED is a tool that is easy to use to design a concept map (easy to find the information I needed)	1	1	2	15	13	32
	Entitled	Q5	SANED is a tool that has made it easy for me to progress through my learning process (knowledge and skills acquisition)	0	2	7	11	12	32
Usefulness	Performance	Q6	SANED is a tool that has allowed me to improve my results.	0	3	11	12	6	32
	Productivity	Q7	SANED is a tool that increases my performance (redress my learning situation promptly)	1	0	3	16	12	32
	Efficiency	Q8	SANED is a tool that makes my learning more effective.	1	0	1	17	13	32
	Transfer	Q9	SANED is a tool that will be useful in my studies.	1	0	2	13	16	32
Intended use	Plan	Q10	SANED is a tool that I will regularly use in my learning from now on	1	3	6	11	11	32
	Choose	Q11	If they make me choose between Moodle and SANED. I will choose SANED	0	2	3	9	18	32
Cognitive load	Mental requirement	Q12.	In SANED, I need to do a lot of mental and intellectual activity to perform a task	3	2	8	13	6	32
	Effort	Q13	In SANED, there are too many steps to complete a task	0	4	6	15	7	32
	Frustration	Q14	During your apprenticeship in SANED, you felt discouraged, stressed, and without assurance of success	20	3	8	1	0	32

Table 5 Questionnaire 2 on the question 'What do learners think of SANED assistance? And the overall number of headcounts

	Closed questions	*Strongly disagree*	*Disagree*	*Neither agree nor disagree*	*Agree*	*Strongly agree*	*Total*
Q15	SANED offers two support mechanisms (implicit and explicit) which largely meet the expectations of students with difficulty	1	0	3	9	19	32
Q16	SANED has a support mechanism for the use of the system, which is offered to each user upon registration and before they show signs of technical difficulties. It provides textual explanatory messages or illustrative videos. Do you find this tool useful?	0	0	4	7	21	32
Q17	The difficulties detected by SANED implicitly (technical, learning, assessment, Interaction, and Support) encompass the most relevant ones	0	4	6	16	6	32
Q18	SANED offers support in different formats (text, image, video, and sound recordings); This makes the support more appropriate and more noticeable	2	1	1	6	22	32
Q19	The given feedback (displayed message) is understandable, clear, and gradual	0	1	1	14	16	32
Q20	The assistance offered in SANED describes the difficulty so that it is better understood by the learner and gives advice or a recommendation for overcoming it. Do you accept this approach?	2	0	2	12	16	32
Q21	SANED has a tool for evaluating the assistance offered and the active assistants. Will this tool help them to find answers to their questions?	1	0	1	18	12	32
Q22	The commitment of teachers and administrators in assisting learners makes SANED very effective	0	2	1	10	20	32
Q23	The rating tool for learning objects, support requests, forum responses, and FAQs in SANED helps to indicate the most relevant support to users and the system	0	0	5	13	14	32
Q24	Showing the teacher the list of learning objects that learners have had difficulty with (Evaluation Statistics), and allowing them to improve or replace them with others, allows SANED to be responsive to learners' difficulties, scalable, and efficient	0	1	5	14	12	32
Q25	Providing the teacher with feedback on the results of assessments, and allowing them to intervene and offer advice to learners showing signs of difficulty, makes SANED an essential tool for success (especially for average and weak students)	0	1	2	14	15	32

4.2 Methodology

Through the first question, we focus on the usability and usefulness of SANED. Two factors were used by several valid models in the literature (Davis, 1989; Lund, 2001; Lewis et al., 2013). We opted for the technology acceptance model (TAM), which gives a prominent role in the user's attitudes. The original TAM model was extended into later versions, and additional second-level factors were added, such as intention and cognitive load. To measure these various factors, we created Table 5 a 14-item questionnaire using an updated version of the Davis questionnaire (Davis, 1989). Each item is rated on a 5-level Likert scale ('strongly disagree' to 'strongly agree'). The study by Tullis and colleagues (Tullis et al., 2004) indicated that this scale was reasonably sensitive and could distinguish between a poor and a well-designed system. The questionnaire in Table 4 has been developed to validate the first question through experience.

The second question investigates how learners perceive the various support mechanisms available through SANED. To that end, an 11-point questionnaire was created and scored using a 5-point Likert scale ('strongly disagree' to 'strongly agree').

4.3 Results and discussion

RQ 1 How do learners perceive SANED's usability and usefulness (as a technological product)?

The percentages headcount table and the cumulative percentages table were constructed to divide the total participants into two groups using the data collected and presented in Table 5. The first column, under 'agree,' contains students who chose 'agreeing' or 'strongly agreeing' as their response. The second column, labelled 'disagree,' combines those who were 'undecided,' 'disagreeing,' or 'strongly disagreeing.'

According to the results:

- 87.5% of the students agreed that SANED is usable, while only 12.5% were unsure or disagreed (Figure 6). Additionally, the simplicity of using SANED and learning how to use it received the highest ratings for usability characteristics, scoring 93.75% versus 71.88% for the ability factor (Figure 7).

Figure 6 The usability of SANED (see online version for colours)

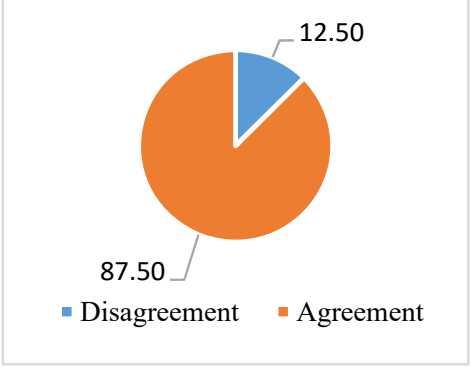
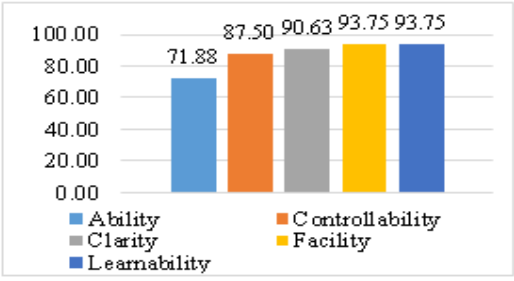


Figure 7 Usability factors of SANED (see online version for colours)



- 82.03% of the students believed SANED was useful, compared to 17.97% who disagreed (Figure 8). Additionally, the learning efficiency factor of SANED is dominant at 93.75%, compared to 56.25% for the performance factor (Figure 9).

Figure 8 Utility of SANED (see online version for colours)

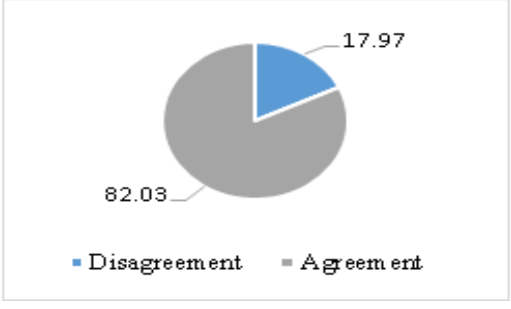
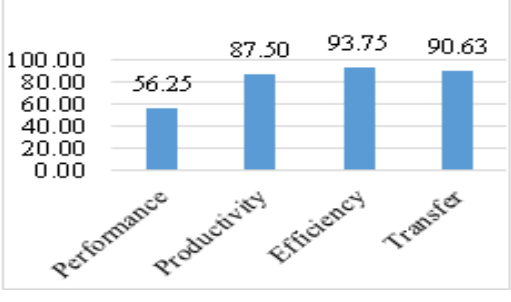


Figure 9 Utility factors of SANED (see online version for colours)



- More than two-thirds of the students (68.75%) were confident in utilising SANED frequently during their course, compared to 31.25%. As for the question of which to choose between Moodle and SANED, 84.375% of the students chose to use SANED (Figure 10). We think this is due to the various advantages associated with SANED, such as customisation, monitoring, and especially support.
- Two phenomena might be seen regarding the cognitive load related to SANED (Figure 11). The first one concerns factors like the mental demand and effort necessary to finish a task, which is around 60% and 69%, respectively; This can be

explained via the learners' brief use of the platform. Regarding the second phenomenon related to frustration, 71.875% of students said they did not feel stressed, discouraged, or assured of achievement, as opposed to 28.125% who said the contrary.

Figure 10 Intent to use SANED (see online version for colours)

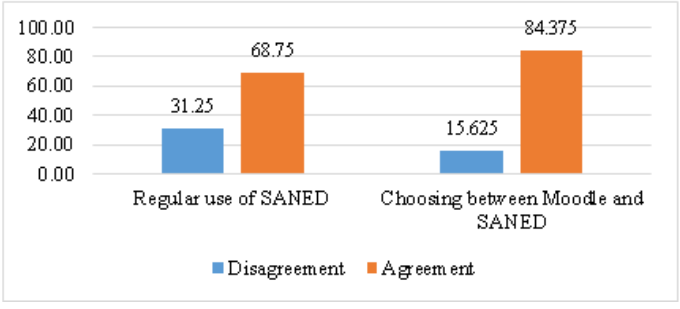


Figure 11 Cognitive workload in SANED (see online version for colours)

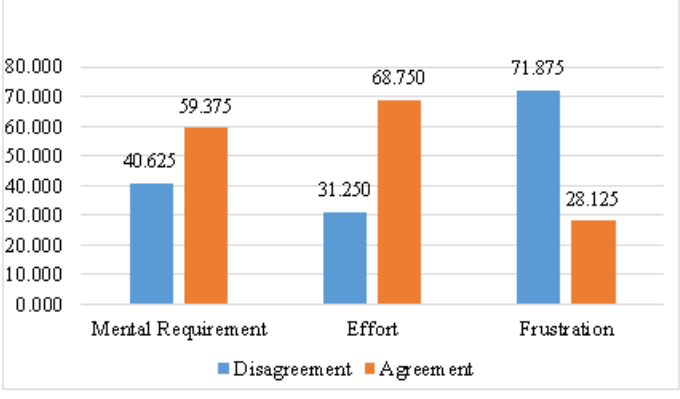


Figure 12 Histogram of the percentages of the headcount for questionnaire 2 (see online version for colours)

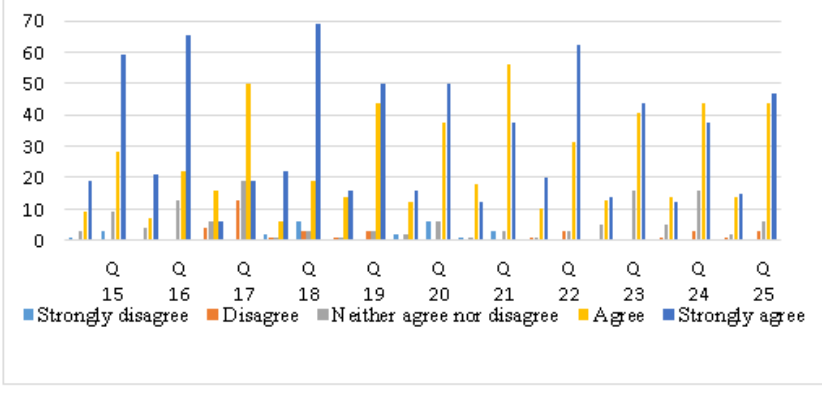


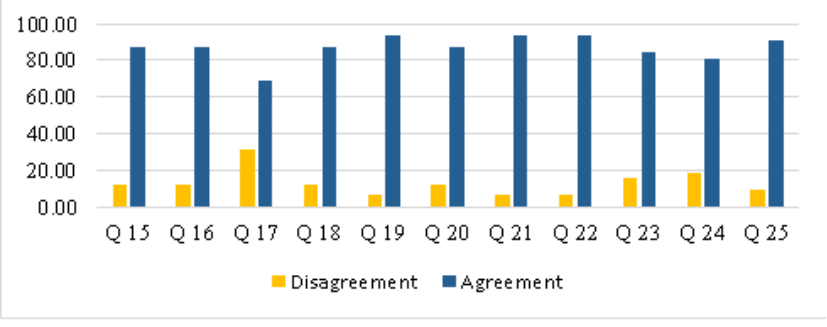
Table 6 Percentage of headcount and cumulative %

	Percentage of headcount					*Cumulative%*		
Questions	*Strongly disagree (1)*	*Disagree (1)*	*Neither agree nor disagree (1)*	*Agree (2)*	*Strongly agree (2)*	*Questions*	*Disagreement (1)*	*Agreement (2)*
Q 15	3.13%	0.00%	9.38%	28.13%	59.38%	Q 15	12,500%	87,500%
Q 16	0.00%	0.00%	12.50%	21.88%	65.63%	Q 16	12,500%	87,500%
Q 17	0.00%	12.50%	18.75%	50.00%	18.75%	Q 17	31,250%	68,750%
Q 18	6.25%	3.13%	3.13%	18.75%	68.75%	Q 18	12,500%	87,500%
Q 19	0.00%	3.13%	3.13%	43.75%	50.00%	Q 19	6,250%	93,750%
Q 20	6.25%	0.00%	6.25%	37.50%	50.00%	Q 20	12,500%	87,500%
Q 21	3.13%	0.00%	3.13%	56.25%	37.50%	Q 21	6,250%	93,750%
Q 22	0.00%	3.13%	3.13%	31.25%	62.50%	Q 22	6,250%	93,750%
Q 23	0.00%	0.00%	15.63%	40.63%	43.75%	Q 23	15,625%	84,375%
Q 24	0.00%	3.13%	15.63%	43.75%	37.50%	Q 24	18,750%	81,250%
Q 25	0.00%	3.13%	6.25%	43.75%	46.88%	Q 25	9,375%	90,625%

RQ 2 How do learners feel about assistance in SANED?

From the headcount Table 5, the percentage table (headcount and cumulative) described below was constructed (Table 6), as well as the clustered histogram (Figure 12) and the histogram of cumulative percentages related to questionnaire n°2 (Figure 13).

Figure 13 Histogram of cumulative percentages for questionnaire 2 (see online version for colours)



According to the results:

- Over 59% of the students agreed that the two SANED support mechanisms (implicit and explicit) meet the expectations of the students with difficulties (question 15).
- 50% of learners agreed that the difficulties implicitly detected by SANED (Technical, Learning, Assessment, Interaction, and Assistance) cover the most relevant ones (question 17).
- 87.50% of the students enjoyed the assistance offered in SANED, which describes the difficulty so that it is better grasped by the learner and provides a tip or recommendation for overcoming it (question 20).
- 93.75% of the students consider the assessment tool for the proposed assistances and the active assistants to be an attractive way to obtain valid answers to their questions (question 21).
- 93.75% of students say that the teachers' and administrators' commitment to assisting learners is fundamental to their success and makes SANED very effective (question 22).
- 90.63% of the students believe SANED is a crucial tool for success because it allows teachers to provide feedback to students who have difficulties after the assessments (question 25).

5 Conclusions and future work

During the last few years, the world has been affected by the coronavirus pandemic, and several countries have adopted online education on a large scale as the only possible solution to continue the educational process. Unfortunately, their users have highlighted

numerous limitations after using these platforms. These limitations and others lead most learners to fail and drop out. Improving e-learning systems has become more than necessary. Therefore, assisting learners in distance learning environments is a promising way to avoid learner overload and improve the quality of teaching.

This article aims to design and implement an integrated support tool within an online teaching platform, relying on trace analysis, to automatically detect the difficulties encountered by the learners that require immediate assistance. We developed SANED, an e-learning dedicated platform composed of three subsystems. The proposed platform is not limited to the support process alone but also includes all the fundamental learning operations and services that all learning management systems provide, such as learning, evaluation, and communication tools.

We tried to answer the research questions raised in the introduction via this platform by identifying learners needing assistance through the trace management subsystem and calculating difficulty indicators. We have also defined five categories of traces (access, learning, evaluation, communication, and assistance) associated with a set of indicators. These indicators are used as input by the Assistance Management Subsystem, which tries to deduce the difficulty faced by the learner, and displays adequate proposals, from the simplest to the most complicated. As a result, several solutions of different types (advice, list of resources, test message) are proposed for the same difficulty depending on the learner's learning profile.

If the learner is not satisfied with the assistance provided, SANED offers additional explicit and practical support tools. He can use the support request form, the DFAQ, and the forum, which allows for regular and rapid feedback on the learners' inquiries, which is essential for learning. Furthermore, the learner can rate the proposed assistance, as well as the assistant himself, as being successful or not, making it possible to display a list of TOP assistances and TOP assistants. The assistance management system uses this data to further improve the proposed assistance and displays the list of good assistants to the learners to allow more successful interactions.

An experiment was conducted to evaluate the impact of the assistance approach adopted by the SANED system on learners' learning. To gather their opinions, we created questionnaires. The test was brief, with a total of 32 students participating in the experiment. Most learners agree that SANED is easy to use and helpful; this can be attributed to how simple it is to use and understand. More than two-thirds of students plan to use SANED consistently throughout their courses, and they significantly prefer it over Moodle because of its adaptability, monitoring, and support in particular. Due to the platform's brief usage duration, the two components of mental demand and effort to accomplish a task about the cognitive load of SANED were both above average. Regarding the frustration factor, students were not discouraged or stressed.

Concerning the assistance component, the two mechanisms proposed by SANED meet the expectations of learners in need. Moreover, some students agree that the difficulties detected implicitly include the most relevant ones. In addition, they appreciate the help provided in SANED, which describes the difficulty so that the learner better understands it and provides advice or recommendation on how to overcome it. Learners report that the commitment of teachers and administrators to assisting learners is fundamental to their success and renders SANED very effective. They also consider the tool for evaluating proposed assistances and active assistants to be an attractive way to get valid answers to their questions. Learners also felt that teacher's feedback provided to

learners showing evidence of difficulties following the results of their evaluations makes SANED an essential tool for success.

In future work, we hope to introduce new metrics for learners' motivation and engagement. Also, we intend to include a new tool for video annotation to assist e-learning. Finally, we want to conduct more experiments to validate the proposed approach using additional, larger samples, over numerous learning sessions, and with statistical analysis-inspired classification methods.

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Appendix

Table A7 Indicators related to communication traces

Traces	*Indicators*	*Rules*	*Interpretation*
Communication via email	Nbr_ME	Number of mails sent < 3 (per week)	Low rate of sending messages
	P_MC (%) percentage of emails consulted	$\frac{\textbf{Nbr\_MC} \times 100}{\textbf{Nbr\_MRc}} < 25\%$ **Nbr_MC:** Number of emails consulted (read) **Nbr_MRc:** Number of mails received	A low ratio of message views to messages received
	P_MR (%) percentage of mails answered	$\frac{\textbf{Nbr\_MR} \times 100}{\textbf{Nbr\_MRc}} < 25\%$ **Nbr_MR:** number of mails answered **Nbr_MRc:** number of mails received	A low ratio of responses to messages received
Communication via forum	P_SP (%) percentage of applicants	$\frac{\textbf{Nbr\_SP} \times 100}{\textbf{Nbr\_ST}} < 25\%$ Nbr_SP: Number of subjects applied for Nbr_ST: Total number of subjects	A low ratio of applicants to the total number of applicants
	P_RP (%) percentage of responses applied for	$\frac{\textbf{Nbr\_RP} \times 100}{\textbf{Nbr\_ST}} < 25\%$ Nbr_RP: number of postulated responses Nbr_ST: total number of subjects	A low ratio of postulated responses to the total number of subjects

Table A8 Indicators related to learning outcomes

Traces	*Indicators*	*Rules*	*Interpretation*
Consultation of materials	Nbr_CM	Number of consultations of a subject (per week) = 0	Low material consultation rate
Consultation of LOs	Nbr_COA	Number of LOs of a subject (per week) = 0	Low LO consultation rate
Consultation of educational resources	Nbr_CR	Number of views of a resource = 0	Low rate of resource viewing
	Nbr_TR	Number of downloads of a resource = 0	Low resource download rate
	Dur_V	Viewing time (Video/Video conference type resource) ≤ ¼Time	Short video asset viewing time
Search in the FAQ (educational questions)	Nbr_RFP	Number of search operations in the FAQ on pedagogical issues (personal week) = 0	Low research rate in the pedagogical FAQ

Table A9 Indicators related to traces of assistance

Traces	*Indicators*	*Rules*	*Interpretation*
Use of the support request section	Nbr_DE	Number of requests sent < 3 (per week)	Low rate of requests for assistance per week
	P_DC (%) percentage of requests consulted	$\frac{\mathbf{Nbr\_DC}\times 100}{\mathbf{Nbr\_DRc}} < 25\%$ Nbr_DC: number of requests consulted (read) Nbr_MRc: number of applications received	The low ratio between the number of assistance requests consulted and the total number of requests received
	P_DR (%) percentage of requests answered	$\frac{\mathbf{Nbr\_DR}\times 100}{\mathbf{Nbr\_DRc}} < 25\%$ Nbr_DR: number of requests answered Nbr_DRc: number of requests received	Low ratio of responses to requests for assistance to the total number of requests received
Using the FAQ section	P_QP (%) percentage of Questions applied for	(Nbr_QP×100)/(Nbr_QT)< 25% Nbr_QP: number of questions applied for Nbr_QT: number of totals questions	Low
Search in the FAQ (technical questions)	Nbr_RFT	Number of FAQ search operations on technical issues (per week) < 3	Low search rate in the technical FAQ per week

Table A10 Indicators related to evaluation traces

Traces	*Indicators*	*Rules*	*Interpretation*
Evaluation of a learning object (LO)	Note_OA self-assessment note from an LO	$\frac{\sum_1^n \mathbf{Note\_EOA}}{\mathbf{Nbr\ EOA}} < \text{Nbr\_QT}/2$ Note_EOA: Note of an LO assessment Nbr_EOA: number of evaluations of a LO Nbr_QT: total number of questions in the assessments of the same LO	The low score in the LO self-assessment
Carrying out evaluations	Nbr_EOA	Number of resolved self-assessments of a LO < Nbr_ET Nbr_ET: total number of assessments of the same LO	Low rate of implementation of LOs
Assessment of a subject	Note_Mat	Final subject self-assessment, the score is between 0–9	The low score in the subject
Failure of a self-assessment	Nbr_TE	Number of attempts at self-assessment > 3	High rate of failure of a self-assessment