Monitoring Student's Curricular Performance in Higher Education

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Abstract Nowadays higher education students are exposed to high levels of stress, and are constantly harassed with distractions that compromise objectives and performance levels found in terms of study and learning outcomes. Correspondingly, higher education institutions do not have at their disposal appropriate tools to follow in real time students' curricular performance. This provides a significant delay in problem identification and will, in turn, have a negative impact on the institutions quality. The problem can be addressed by using a business activity monitoring system that monitors the curricular performance of students throughout their academic endeavor. By providing teachers and students with an informational cockpit that outlines a set of indicators, providing clear context awareness about their performance, we allow them to follow their evolution and progress in accordance with the acquisition of knowledge objectives expected by each Higher Education Institution. Allied with alarming mechanisms, such a cockpit would greatly increase the control students and institutions would have on their activities. By applying corporate concepts used today in the business world, we propose a real time business activity monitoring tool by defining key structural elements such as information models, activity monitoring models and dashboard design applied to a higher education environment.

Keywords: Business Activity Monitoring, Higher Education, Dashboard, Indicators, Information Model.

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1 Introduction

This thesis proposes a monitoring model solution to follow the curricular performance of a higher education student. This document is structured logically to allow the reader to understand the problem addressed and its challenges, followed by a clarification of the concepts involved and their pertinence in the market today, and ending in the solution proposal and evaluation methodology as a result of the work done.

The current chapter contextualizes the thesis's theme and identifies the research challenges and objectives in this work. It is structured as follows:

1. Context – presentation of the context in which this work done;
2. Research Challenges – problem definition and challenges related to the research work;
3. Goals – objectives of the research that address the challenges and problems identified in the previous section;
4. Main Contributions – main contributions that the research work offers in accordance with the established goals defined in the previous section;
5. Document Structure – presentation of the document's main structure;

The following subchapter contextualizes the thesis's theme.

1.1 Context

The curricular performance of higher education students (HES) does not always meet expectations, be it by the university, professors, or the student itself. This may be caused by a plethora of reasons, some of which include lack of planning and monitoring of the academic endeavor. This is a situation that is undesirable not only by the student itself that will suffer from poor performance, but also by the institution in which he is enrolled, since the said performance reflects on the institution's quality and reputation. This is a common situation in education however little research has been done on how this problem can be solved.

This thesis focuses, for that reason, on developing research work on the subject, by modeling a business activity monitoring (BAM) tool to visualize important information relative to HES performance through the use of dashboards. A dashboard will, therefore, be used as a tool to support the management and monitoring of higher education activities and, as such, assume the role of a personalized informational cockpit adapted to a user profile (teacher, student, manager). This dashboard features information presentation through key indicators (in a graphical form) and through alerting capabilities, allowing analysis, control and visibility over curricular activities.

The development of this work involves researching concepts and best practices related to the topic of BAM, dashboard and model construction; case study analysis of FénixEDU an academic management system developed by Instituto Superior Técnico (Lisbon Tech); and surveying existing systems and performance indicators used by higher education institutions;

For the proposal of the monitoring tool, a five step procedure was defined for the creation of a model. This procedure involves the characterization of the approach towards the definition of an information model, definition of monitoring objects, dashboard design, definition of events, and data and presentation rules. For the modeling work the tool Enterprise Architect 10 is used, and in accordance with the design science research methodology, in which we follow its seven guidelines for the creation and validation of three artifacts: information model, monitoring model and dashboard design.

1.2 Research Challenges

Student pedagogic and curricular success is measured by the necessary and expectable knowledge acquisition throughout the academic endeavor. Control over this knowledge acquisition is critical and must be done in order to ensure the fulfillment of objectives within a higher education institution. This control needs to be present in two main perspectives. From an institution's perspective (stakeholders include teachers and managers) there are concerns with the quality and performance of its education which is positively correlated with the performance of its students. From the students' perspective (in which the stakeholders are higher education students) there are concerns with personal curricular accomplishment and achieving the highest possible grade as well as acquiring knowledge. Each perspective has its own concerns and problems, and hence different informational needs. We approach each perspective in the following paragraphs.

From the institutions perspective

Most evaluation plans in higher education institutions produce and revise student grading at the end of an academic term (typically a semester). In these plans the degree to which a student is considered to be successful is contingent upon how good their final grades are. This information is commonly used to identify areas and students that are having poor academic performance. Higher education institutions are not sufficiently aware about the relevance of personalized tracking and monitoring of each student's progression. In most situations there is a lack of tools, endowed with alarming mechanisms, capable of acting preemptively when confronted with a deficient student's plan and progress in an early stage of development. One of the inherent disadvantages associated with this type of reactive evaluation, is the fact that by the time this is done it is too late to address the underlining causes of unsuccessfulness of the academic term.

From the student perspective

With the current demand of a competitive professional market, higher education students are increasingly being overloaded with large amounts of tasks and information as well as other distractions that require their attention. This situation has the potential of not only decreasing the study efficiency but also makes it difficult to put in effect an adequate study plan. The lack of planning capabilities and the need for academic integration further aggravate this state, and students are faced with the inevitable situation of falling behind on their studies. Since students do not have at their disposal control and monitoring mechanisms related to their academic endeavor they will, at some point, be faced with missing project and report deadlines, lack of study, lack of planning and time allocation to study.

Why is it a problem

- When events with negative performance are identified it is usually too late to address the underling causes. This reactive evaluation causes a lag between problem identification and problem resolution;
- One or the major criteria to classify Higher education institutions is normally based on a ranking defined by the quality of its graduates. Lack of monitoring and problem resolution may mean a decrease in the quality of education and hence the quality of an institution;
- Students usually fall behind on their studies due to lack of control mechanisms relative to their academic endeavor;
- Lack of monitoring capabilities can account for deficient and untimely decision making.

How to address the problem.

The use of automatic monitoring and alarming mechanisms capable of presenting aggregated and systemized data to support, in real time, stakeholders information needs. This type of monitoring can be implemented using a set of indicators configured in accordance to the role and profile of stakeholders by:

- Providing teachers with an informational cockpit with information about the student's progress and performance. The use of key indicators helps at accomplishing this goal, allowing simultaneously to get a good perception about each student learning progress and with additional information in relation to average teaching standards;
- Providing students with an informational cockpit with information designed to cope with their learning concerns. Such approach also allows them to monitor how well they are performing in relation to the thresholds defined in their area;
- Providing alerting mechanisms to teachers and students that preemptively notify them, with different levels of severity, of low performance areas and risks.

This leads to the need of having a set of classification information, namely: metadata about the student's profile, metadata about the business rules, and metadata of the informational cockpit.

Work Challenges

Modeling a monitoring system capable of addressing the problems referred, presents challenges in three levels:

- Data Definition
  - Define an adequate information model structure capable of supporting the monitoring process;
  - Define, select and categorize a set of key indicators that allow monitoring the pedagogic progress of a higher education student;
- Event Processing
  - Comparative analysis of the individual performance of a student against the performance of a group of students (such as all the students in a course);
  - Event treatment with alert mechanisms associated to different levels of threat regarding the performance of an academic student;
  - Flow specification of events and associated alerting mechanisms;
- Presentation and Display
  - Model and design a dashboard interface capable of addressing the challenges identified in this chapter.
  - Present concise and systemized information in a way that is suitable for a higher education context and for each role within it;
  - Display of alerts and notifications differentiated by different levels of granularity;

1.3 Goals Addressed Within This Thesis

This thesis aims at improving the pedagogic performance of higher education students by providing a specification of a real time activity monitoring model, adapted to a higher education context by achieving the following goals:

- Specify an information model to support higher education business activities and events;
- Conceptualize a solution for a real time activity monitoring model, supported by the defined information model;
- Design a graphical visualization interface (i.e., dashboard) capable to support stakeholders' information needs according to their role and expectation to reach established goals.
  - Institution: achieve high quality standards and gain reputation;
  - Teacher: career progress through pedagogical excellence, research recognition;
  - Student: conclusion of studies within the right time, acquisition of knowledge, and achieve the best possible results;

We will be focusing mainly on the students' perspective but, as said above, students' results reflect on their teachers and on their institutions. The achievement of these goals opens the possibility for comparative analysis between students' progress, not only in their current year, but in previous years as well. Consequently, in the teacher's perspective, it will be possible for a better and personalized pedagogic performance monitoring of the student.

1.4 Main Contributions

The main contribution of this work will be the specification for the development of a monitoring tool with a dashboard interface, to monitor the curricular performance of students in higher education. With it will be possible to monitor the performance of a student in real time, not only with the dashboard itself, but also through alarming system mechanisms to alert teachers, students and institutions of poor performance areas.

We aim not only at contributing with a technological tool specification, but also at helping students to create good planning, management and control habits in their curricular activities. Providing a tool that helps students acquiring these habits is one of the most important objectives of this work.

1.5 Document Structure

This document is mapped into five sections: Introduction, Related Work, Solution Architecture, Case Study, Evaluation Methodology and Conclusion.

Section 2 presents the state-of-the-art in activity monitoring; outlines specific topics core to the thesis and describes the main concepts related with information archetypes, and configuration of key indicators based on their metadata. It includes a short overview of graphical techniques used to transmit relevant information to the end-user accordingly to their role and interests. The section also includes a description of the work performed at analyzing tools and methodologies related to the implementation of a BAM solution, with an overview of related research, in particular at using Dashboards to create a decision making informational cockpit.

"Solution Architecture" (section 3) delineates the modeling work involved for the development of the specification of a monitoring model applied to a higher education context. This section contains the requisites and steps required for the thesis solution proposal.

The section "Case Study" (section 4) identifies the existing system *FénixEDU* at Lisbon Tech, the related metrics and indicators present, and the limitations associated with activity monitoring.

Section "Evaluation Methodology" (section 5) defines the validation methodology of this work through the use of design science research, by following its seven guidelines.

Lastly, the section "Conclusion" (section 6) details the attained conclusions and remarks based on the work elaborated.

2 Related Work

This section describes the main concepts, methodologies and studies that pertain to this thesis' theme. In the first four subchapters the concepts of business activity monitoring (2.1), indicator (2.2), dashboard (2.3) and information model (2.4) are explained and developed as part of the research work. Chapter 2.5 reports the author's involvement in a dashboard related project development in an INOV team, followed by chapters 2.7 and 2.8 which refer to recent studies and state-of-the-art respectively.

2.1 Business Activity Monitoring

Business Activity Monitoring (BAM) was first coined by Gartner as a term to define real-time access to critical business performance indicators to improve the speed and effectiveness of business operations [18]. BAM features its information display through the use of dashboards containing key indicators (KI), assuring activity and performance visibility.

A BAM system collects data from multiple sources which, given a context, results in capturing events [10]. Events are occurrences in time and in a given context that can be monitored and analyzed using business rules and indicators. This analysis allows the correlation between events so that tendencies can be detected and predictions can be made on the outcome of certain events. A four step procedure is described by [3] for the design of a BAM system (

Fig. 1).

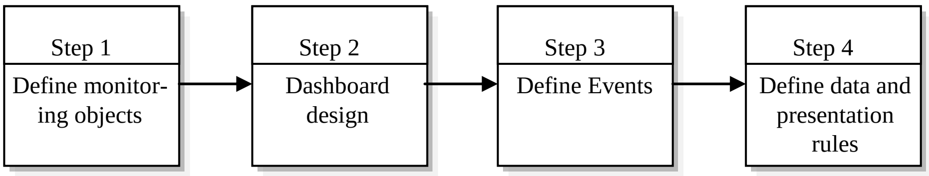


Fig. 1. BAM Design Procedure

The procedure involves:

- Definition of monitoring objects for real-time performance measurement – selection of which objects should be measured in real-time. In the context of this thesis, the objects correspond to KI. The process of definition involves the understanding of how an organization works and what types of measurements are needed to achieve the organization's progress and goal achievement (see section 2.2 for more detail);

- Dashboard Design – define and design schematically the structure and display format of the dashboard. A careful planning of KI relationships and position should be considered (see section 2.3 for more detail);
- Definition of events for monitoring – which events should be monitored in accordance with the monitoring objects selected previously (more specifically KI) as well as defining the context in which these events occur;
- Definition of data stream and presentation rules – specification of the flow from the event extraction to the presentation and definition of the presentation rules such as alerting mechanisms (see section 2.2 for alerting mechanisms) and refresh periodicity;

This thesis will extend this method by creating an additional step which involves the definition of the underlining information model of the monitoring objects (refer to section 3).

2.2 Indicators

In order to effectively monitor a business activity it is essential to have business indicators. We can divide these into two types: basic indicators which are the direct result accessing a measure value (or metric), and derived indicators which are the result of the computation of basic or derived indicators. Derived indicators are typically associated to key indicators (KI) [17]. A KI is an indicator that is relevant to an organization's goal and objectives, and for the purpose of this thesis three types of Key Indicators will be worked with, these are Performance Indicators (KPI), Risk Indicators (KRI) and Control Indicators (KCI).

- **Key Performance Indicator** – a measurement of an organization's performance. KPIs are used to answer the question: "Is the organization achieving the desired levels of performance in accordance with the established goals". It's applied for historical analysis since they refer to a period of time.
- **Key Risk Indicators** – a measurement which is used to define and monitor an organization's risk and its changes. KRIs are used to answer the question: "How an organization's risk profile is changing and how does it fit within established tolerance levels". It's applied for real time analysis of critical business activities and provides some degree of predictability of what will happen if nothing is done to address a risk.
- **Key Control Indicators** – a measurement used to define and monitor an organization's control environment. It is used to answer the question: "Are the organization's control measures effective". It's applied for real time analysis as well as providing insight about tendencies within critical business activities.

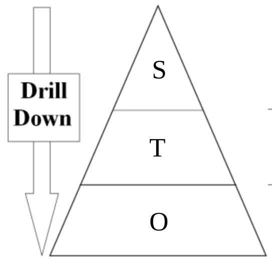
A business indicator should have associated meta-information with the characterization of the spatial and temporal context [17] allowing the correlation of events and indicators. Within a spatial and temporal context the KIs presented must have associated thresholds that limit optimal values for a given activity. The thresholds vary for each indicator and within each context, and are framed into three indicator groups: benefit indicators (the bigger the measure the better) in which a threshold defines a lower bound, cost indicators (the lower the measure the better) in which a threshold defines an upper bound, and on-point indicators (the closer to a predefined value the better) in which a threshold defines a lower and upper bound. Furthermore each type of KI (KRI in particular) must have associated alerting mechanisms that trigger when a certain threshold is crossed, and each associated with different levels of severity.

The concepts covered (KI, context, thresholds and alerting mechanisms) only have significance when correlated with different analysis perspectives, or in other words, actors and context. Each actor has different informational needs and in relation to a particular context. These perspectives can be characterized in a three level information structure: Operational. Tactical, Strategic; as shown in **Table 1**

These perspectives have different levels of visibility; starting with the lowest visibility level, the Operational perspective presents detailed information relative to a specific activity, and hence has the objective of monitoring said activity. The Tactical perspective offers a more generalized view than the Operational by presenting aggregated information over several activities. This perspective allows analysis by comparing performance over different activities, while also allowing the monitoring of general indicators in each one. In the highest level of visibility we have the Strategic perspective which offers a very generalized and concise view over all, or a big part of, activities. The information presented is extremely aggregated and the objective is the analysis of the overall performance of an organization.

The highest levels of visibility (Strategic and Tactical) are typically associated with managers, and in the context of this work these refer to school directors and course administrators. In this case a school director would assume a strategic perspective due to the nature of managing an institution; he would need global view of all activities with aggregated information. A course administrator, however, would only need visibility over a set of modules belonging to a given course, so he would assume a tactical perspective with information about each course module.

The lowest level of visibility (Operational) is typically associated with business workers/operators that need to know how a particular activity is performing. In the context of this work these would refer to teachers, since these need detailed information about their class and student performance.



Perspective	Objective	Information
Strategic	Analyze	Very Aggregat-ed
Tactical	Analyze + Monitor	Aggregated
Operational	Monitor	Detailed

Table 1. Information structure with comparative perspective analysis of key indicators

Each perspective must have associated drilldown capabilities that allow the navigation through the information structure. Drilldown provides a method of exploring multidimensional data by moving from a higher level of visibility to a lower level of visibility.

Due to the transmission of large amounts of implicit information an indicator value should be represented in a graphical form in order to better perceive information relationships, which will be discussed in the following subchapter.

2.3 Graphical Interface to Support the Monitoring Process

It is not enough to define a set of indicators. These must be displayed in a manner that is adequate to a given context and role [1], efficient and easy to use, and must be presented in a way sufficiently intuitive so that no additional "know-how" is required. This is why indicators are typically represented by graphical objects via user interfaces.

One such form of graphical interface is designated as Dashboard. Stephen Few [12], one of the leading experts in this subject, defines it as being:

> *"… a visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance."*

This definition is somewhat agreeable. It states that only information needed to achieve an objective (which is the definition of a KPI) is presented. However other types of information may be relevant, in particular KRI or KCI. Furthermore it lacks the statement of how information is displayed, it should be added that the visual display makes use of graphical objects (e.g. charts, gauges and tables). We therefore present our own definition:

> *"A dashboard is a visual representation that makes use of graphical objects to display the most relevant information, consolidated in a single screen."*

Regardless of definition, an effective dashboard should display aggregated and concise information needed to achieve specific objectives, and permit visualization at a glance. The display mechanisms should be clear, intuitive and appropriate to the context of the information, as well as adapted to the specific requirements of a given person, group or function [12].

Information Representation

Information in dashboards can be divided into two types, Spatial information (presented in the form of charts and gauges) which is suited for spatial tasks that involve forecasting and comparisons, and Tabular information (presented in the form of tables) which is suited for symbolic tasks such as extracting specific values.

The relation between the information presentation format and the associated task is characterized by Cognitive Fit Theory, which provides guidelines on choices of presentation formats [13]. Cognitive fit theory proposes that the performance of a task is related to the cognitive fit (match) between the information presentation format and the task type (**Fig. 2**). A complete match will lead to a superior task performance for individual users [14].

For instance, a stock market analyst that needs to check on specifics values referring to the current market share of specific companies (task type) would benefit most from using a table (presentation format) with the company name and market share as columns, ordered by the name. However if the goal is to compare market shares from different companies on a given market segment, then a pie chart would be more appropriate.

Furthermore visual components should be carefully organized and synergized with each other. Size, color and position of each individual component is crucial to ensure the information is evidenced correctly and components that are related should be closer together [8].

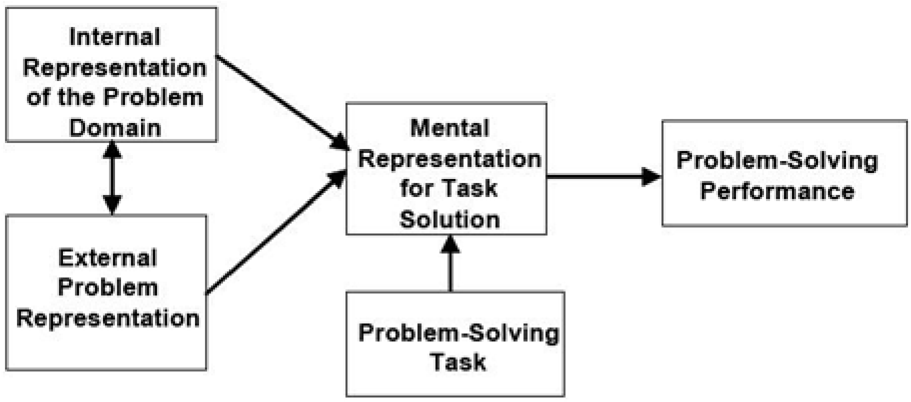


Fig. 2. Extended Cognitive Fit Model, extracted from Shaft[1]. The performance of a task is positively correlated with the information presentation format and the task type.

For the purpose of this investigation the focus will lie on five graphical objects (visual components) divided into these two formats, Spatial and Tabular. For spatial information the focus will be on line charts, bar charts, pie charts, tree maps and heat grids. For tabular information the focus will be on table representations.

Metadata

As was said earlier, a dashboard must be adapted to a specific context, and it is described through the use of metadata. Metadata is a term to define “data about data”, i.e. structured information that describes characteristics of a set of data as well as relations between data and business activities. As an example associated to dashboards we have: dashboard description, name, owner, target, etc. Metadata also facilitates user interaction by allowing the understanding the reason of the occurrence of events (see section 2.2).

2.4 Information Modeling

An Information Model is a generally formal and abstract representation of entities and their relations, which can include properties and operations. In [19] an information model is defined as being:

“*(…) a representation of concepts, relationships, constraints, rules, and operations to specify data semantics for a chosen domain of discourse.*”

[1] Source: Shaft, Teresa M. and Iris Vessey, (2006) "The Role of Cognitive Fit in the Relationship between Software Comprehension and Modification", MIS Quarterly, Volume 30, Issue 1, pp. 29-55

Using an information model provides an organized and stable structure of information that has the advantage of being able to be integrated with identical or similar structures. Mainly three types of model methodologies have been used in recent years: object-oriented (OO), entity-relationship (ER), and functional modeling [19]. We will focus on the first two methodologies beginning with a description of each approach, followed by a comparison of the advantages and disadvantages of each one.

- **Object-oriented approach** – based on a collection of objects, each one with its own data structure and functions. An object can be defined as a value or object class, each class can have values (attributes) and operations (methods), and each class can have an association (relation) to another object. Object classes can communicate by invoking methods from different objects. The OO approach has the advantage of being easier to model complex objects, allowing better extensibility than other approaches, and allowing integration with OO models. The disadvantage lies on the fact that this approach considers both the data and the functions in its model, contrary to ER, for example, that only considers the data;

- **Entity-Relationship approach** – based on a graphical notation technique an ER model is structured in entity type, entity relationship type and attributes type [19]. Each entity may have multiple attributes and can be associated with other entities thru a relationship but contrary to an OO approach, an ER model does not represent behavior (functions). ER models are easy to understand and are widely used in database systems to represent their table structures. This approach is suited for high level of detail of data requirements.

	Object-Oriented Models	Entity-Relationship Models
Advantage	Easier to model complex objects Better extensibility Better integration and maintainability	Better suited for detailed data Easier to understand
Disadvantage	Considers data and functions	Harder maintainability and integration Structure updates are often needed due to function related requirements

Table 2. Comparative analysis between OO and ER models

An OO approach offers better extensibility, maintainability and integration when compared with an ER approach. An ER however is simpler in that it only considers data, when compared to OO that considers both data and functions.

Choosing an appropriate modelling methodology is essential to begin modelling work, and a carefull consideration of the advantages and disadvantages must be made. In section 3 we will choose a methodology based on this chapter's analysis.

2.5 PEGSS – INOV Project

Plataforma Electrónica de Gestão de Serviços de Saúde (PEGSS) is a project promoted by INOV and Sinfic. The project consists in the development of a web based platform for a dynamic single page application dashboard engine. The platform will allow the creation of dashboards on demand and on the spot, and is applied to a medical context. PEGSS adopts the object-oriented Reference Information Model, an international Health Level 7 standard (refer to section 2.8), which will also be used on our architecture solution (section 3).

The author is currently part of the development team, in parallel with this research work, by contributing with source code (HTML and JavaScript) for the creation of graphical dashboard components, mainly objects of the type content, graph object and toolbar which will be described in the following paragraph. The development work involves a study and analysis of the latest state-of-the-art technologies for graphical content creation (e.g. dynamic charts and tables, toolbars and data structures), their implementation and subsequent integration in the project.

In the context of PEGSS, a dashboard is characterized by four main objects: visualization window, content object, data item, and graph object. The visualization window consists in the "single page" display area of the dashboard; it has associated descriptive metadata with information about the owner, permission privileges, description, among others. The visualization window contains one or more content objects. A content object represents the "container" in which the graphical dashboard components are represented; it has associated descriptive metadata regarding information about associated data items, associated graph objects, description, data sources, among others. A content object is always associated to a toolbar, a graph object, and at least one data item. A toolbar allows the manipulation of a graph object as well as editing and updating content metadata. A graph object corresponds to the graphical representation of a data item, which, in the current stage of development, can be represented through pie charts, bar charts, line charts and tables. Finally a data item consists in the data collected from a data source such as a database or ERP for example.

2.6 Activity Monitoring in Portuguese Higher Education Institutions

In order to assess the current state of activity monitoring in higher education in Portugal, a preliminary study was made with the purpose of finding which academic platforms are used in institutions in the area of Lisbon. The adopted method consisted in surveying, by distribution of questionnaires via Google form, and internet research (results in Anex A). The results obtained show that the majority of institutions use either NetP@ or Moodle. NetP@ is an academic portal that allows students, teachers, employees and candidates to access a set of dedicated services. Upon student and teacher inquiry, these services were found to be of management and logistical nature, and no evidence was found for real-time monitoring capabilities. Moodle is characterized as being a learning management system that allows the creation of online dynamic web sites for students/professors. It provides educators with tools to manage the learning process of students[2]. Moodle does have available dashboard plug-ins, but these have limited capabilities and are not capable of the type of monitoring proposed by this thesis.

Further research on these systems showed that they are mainly used for management activities, with services that include, but not limited to, class enrollment, project submissions, evaluation registration, online payments, schedule assignment and grade visualization.

2.7 Recent Studies and Research

Part of the Egyptian' Ministry of Higher Education (MOHE) strategic plan to reform higher education in Egypt involved the Program of Continuous Improvement and Qualifying for Accreditation (PCIQA) which was responsible for monitoring projects sustainability and institutions developments. PCIQA developed a tool based on the balanced scorecard methodology that would be used for self improvement monitoring and performance measurement in Egyptian Higher Education institutions. The developed tool was sufficiently flexible to allow each institution to set KPIs and weights in accordance to

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[2] Source: moodle.org/about/

their mission and strategic goals. This was accomplished through the use of key performance indicators categorized into six perspectives: Educational and learning excellence, Scientific research excellence, Community participation, environment development, and stakeholders, Human and material resources, Financial resources, Institutional capacity and quality management. These perspectives would then be used to calculate the overall performance of a higher education institution [9]. This study will be considered for solution architecture in this thesis, namely the definition of key indicators applied to a higher education context (section 3):

A study performed by Velcu-Laitinen and M. Yigitbasioglu, two researchers from Aalto University (Finland) and Queensland University of Technology (Australia) respectively, reported on the results of a survey with sales managers regarding the use of dashboards in Finish companies. These sales managers used dashboards to monitor, locate and resolve problematic business areas, and guarantee the consistency of their business activities. A high correlation between dashboards and user productivity was found, which indicated that dashboards were perceived as effective tools not only for monitoring, but to increase productivity as well. Velcu-Laitinen and M. Yigitbasioglu considered perceived dashboards not only as a means to present information, but as a tool for real-time notifications, different layered analysis perspectives with the presence of drilldown capabilities, and scenario analysis of projected events [5]. This study further evidences that features of a dashboard are not limited to display key indicators, but also include alarming mechanisms (notifications) and perspective analysis with drilldown capabilities. These last two were demonstrated to have an important role in monitoring key activities within a business.

2.8 State-of-the-art

In the following subsections we will approach the concepts covered above from the current market point of view. We will present and discuss the latest state-of-the-art technologies, tendencies and tools available.

Business Activity Monitoring

Performance measurement has been a big concern for companies, particularly big organizations that deal with large amounts of data, and with today’s highly competitive market no one can afford to lose visibility over their business. Because of this, it is no surprise that companies use monitoring systems to take control over their activities. One such system is based on the concept of Business Activity Monitoring, which was addressed in section 2.1, and is being used successfully with positive and beneficial results [3].

BAM solutions are made available by multiple vendors and are in their vast majority commercial. **Table 3** shows the most significant state-of-the-art commercial and open-source solutions based on research done on the current market (year 2013).

Vendor	Product Name	Type
Oracle	Oracle BAM	Comercial
Microsoft	BizTalk Server	Comercial
IBM	IBM Business Monitor	Comercial
Exact	Exact Event Manager	Comercial
Bizsensors	Gourangi Enterprise Server	Open-Source

Table 3. BAM vendors and respective solutions (2013)

A fundamental key aspect of BAM solutions relies on the presentation of information through a graphical display designated as Dashboard (section 2.3), depicted in **Fig. 3** below.

Fig. 3. Example of Oracle's dashboard from Oracle BAM[3]. Call center scenario, monitoring incoming calls per hour and per region, SLA performance, and alerts. Features spatial (bar, pie and speedometer charts) and tabular information

Dashboard

Dashboards have been around since the early 1900s where they were first created and used in cars, which we still use today. These consisted of various indicators (Key Indicators to be precise) to monitor and display the car's most important information. This concept was adapted to the finance industry in France in the 60s as a way to display different ratios for financial control. These were designated by Tableau de Bord (Dashboard in French). From there dashboards evolved into ever more

3 Source http://www.oracle.com/technetwork/middleware/bam/callcenter-086652.html

complex business aids, and are now used in every major company as a management, monitoring, and decision making tool.

During the last years, software vendors such as Oracle, Microsoft, IBM, SAP, QlikViewm, Pentaho, and JasperSoft, have been developing state-of-the-art dashboard solutions [5]. **Table** 4 presents some of those solutions.

Vendor	Product Name
SAP Business Objects	Xcelsius
IBM	IBM Cognos
Microsoft	Microsoft Business Intelligence
JasperSoft	JasperSoft Dashboard
IDashboards	IDashboard Enterprise Suite
Pentaho	Pentaho Dashboard Designer

Table 4. Dashboard solution vendors (2013)

There are two types of dashboards: static dashboards in which there is no possible interaction with the information displayed, and its purpose is solely to present information be it in real-time or not; and a more interesting cutting edge type of dashboard designated by Business Intelligence Dashboard (also referred to as Enterprise Dashboard) shown in **Fig. 4**.

Fig. 4. IDashboards' Business Intelligence Dashboard demo[4]. Hospital scenario, monitoring physicians and patients treated in a fictitious medical instituition.

BI Dashboards differ from basic dashboards in terms of interactivity and real-time on the spot querying. These allow for drilldown and rollup types of search as well as filtering and ordering by interacting with the dashboard components, it may also permit visual customization such as changing colors and

4 Source http://examples2.idashboards.com/idashboards/?guestuser=wphea&dashID=193

position of each graphical component. **Fig. 4** illustrates an example of interaction by highlighting in every component the information relative to the Doctor picked in the graph in the upper right corner of the screen.

Reference Information Model

Reference Information Model (RIM) is a Health Level 7 (HL7) standard, version 3, for development methodologies [15]. It is an abstract object-oriented model which offers an explicit representation of semantic and lexical connections that exist in messages transmitted in HL7v3. HL7 is a non-profit organization that develops international interoperability standards of electronic health information systems.

The RIM consists of classes assigned to one or more subject area packages. Attributes, Relationships, and State Machines are associated with classes and each class within the RIM represents information about a concept that must be documented and communicated within the health care environment [16].

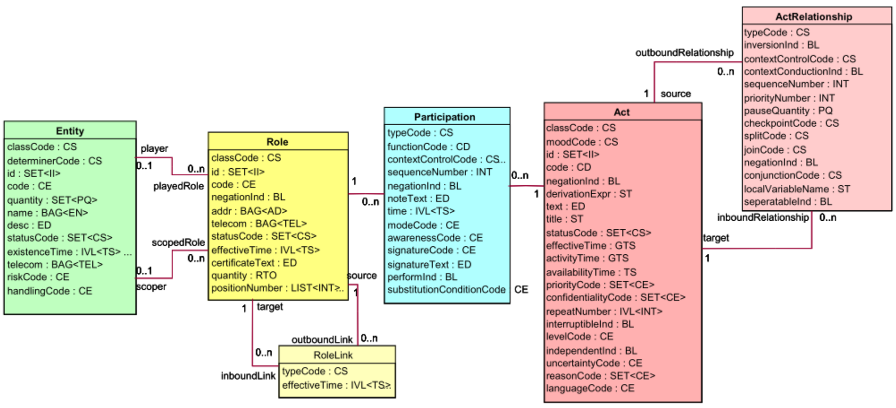

Fig. 5. UML class diagram of the Reference Information Model backbone[5]

The model is expressed using the Unified Modeling Language (UML), and is composed of three main classes: Entity, Role and Act; that are connected by three associative classes: Participation, RoleLink and ActRelationship. Entities are related to Roles, and through their Participations interact in Acts, as can be seen in **Fig. 5**. An Entity represents some physical being that performs a function (e.g Organization and Institutions). A Role establishes the role that entities play and they participate in Acts. Roles can be related to other roles by using RoleLinks. Participation expresses the context for an Act. An Act represents the actions that are executed and must be documented, and can be related to other acts by using an ActRelationship.

[5] Source: [16]

Languages and Methodologies

Unified Modeling Language (UML) is a standard (ISO/IEC 19501:2005) used in the field of software engineering to create software artifacts. It was adopted by the Object Management Group (OMG) and accepted by the International Organization for Standardization (ISO) as an industry standard. Although the language was developed to model object-oriented software systems, it is commonly extended to other domains such as structure and behavior of organizations and other architectural artifacts. UML diagrams can be represented in two different views: Structural view, which emphasizes the structure of an artifact by presenting objects, attributes, operations and relationships; Behavioral view, which emphasizes the behavior of an artifact by presenting collaborations among objects. The structure can be mapped through class, package, and object and domain diagrams. The behavior can be mapped through activity and use case diagrams. We will use the diagrams mentioned for the creation of the architecture solution.

Design science research is a problem-solving paradigm that seeks to *"seeks to create innovations that define the ideas, practices, technical capabilities, and products through which the analysis, design, implementation, management, and use of information systems can be effectively and efficiently accomplished"* [20]. This methodology defines seven guidelines: design as an artifact, problem relevance, design evaluation, research contributions, research rigor, design as a search process, communication of research. These guidelines will be used for the validation of the work produced by this thesis (refer to section 5).

3 Proposed Architecture for a Higher Education Performance Monitoring Tool

This chapter presents a description of the solution architecture and functional requisite specification for a monitoring model applied to a higher education context. As a support to the content of this chapter annexes C through E are submitted in the according section. For the development of this work a five step procedure will be followed (depicted in **Fig. 6**), which is an adaptation from [3] (refer to section 2.1).

The solution involves the creation of a higher education student monitoring model and a dashboard interface for indicator visualization. The dashboard presents key indicators (KPI, KRI and KCI) relative to a student’s performance in its curricular activities. Such activities include, but are not limited to, class attendance, study performance, exam/test attendance, weekly hour reporting, project submission, evaluation results. These are subject to isolated monitoring analysis (e.g. a dashboard relative only to the personal performance of a student) or comparative monitoring analysis (e.g. dashboard with information about the performance of a set of students). Each KI has associated thresholds to limit optimal value ranges that, in conjunction with alarming mechanisms and visual displays, provide a way of showing poor performance areas that need attention from either the student or teacher.

KIs are assigned to different contexts (e.g. course, class, curricular year, etc.) and with regard to a specific user profiles (i.e. student and teacher), allowing for different analysis perspectives: operational, tactical and strategic (Annex C).

Context and profile is characterized in descriptive metadata associated to the dashboard. Context awareness assumes a fundamental role in the definition of this model, since information does not have the same importance for every user role and even for same user roles in different contexts. For instance, for a first year student it is important to have at his disposal mainly operational indicators about his performance in various classes. For a final year student however, his interest lie mainly in analysis of classes done and his progress throughout his studies, which require indicators of tactical or strategic nature.

Navigation is possible between different perspectives through drilldown capabilities. This allows, for example, for a teacher, that is visualizing his class dashboard (with information about all his students), to focus on a single student by selecting him and being presented with another dashboard with KI relative to that student.

The proposed solution is conceptualized through use cases (Annex D) and mockups are presented in this chapter for dashboard display.

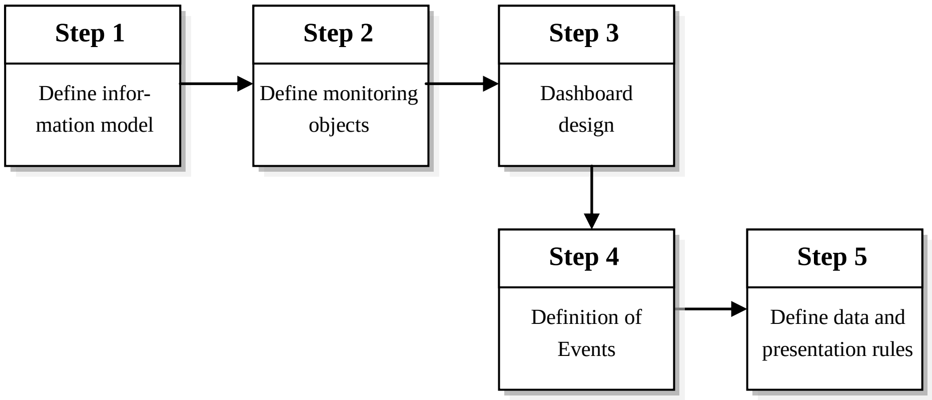

Fig. 6. Steps to implement the proposed architecture, adapted from [3].

A monitoring system must exist to capture and process events in order to translate these into KI which are then used by dashboards. For this reason we present two models to support the presentation of information: monitoring model and information model. The monitoring model will conceptualize how, when and which events are treated as well as defining what objects are subject of monitoring. The information model will define how such objects and events are structured and characterized.

We present in annex E the work plan for the development of the solution proposed in this chapter.

The following subchapters will describe the steps taken to develop the monitoring model.

Step 1: Definition of the Information Model

The information model characterizes objects in a higher education context. These include, but are not limited to, student, teacher, class, course, institution, evaluation components, schedules, roles, activities. For this a gathering of information objects is made via the FénixEDU case study (refer to section 4) and internet research on reference universities.

We consider an object-oriented approach to define the information model, by using the RIM as reference (refer to section 2.8). We chose an OO approach due to its benefits in extensibility, maintainability and integration when compared to an ER approach. RIM is currently a HL7 standard, and is being used successfully in medical-based information systems. A high education institution is in many ways analogous to a medical facility: doctors translate into professors; patients translate into students; treatment rooms translate into classrooms; managers translate into course coordinators. For instance, a doctor follows procedures to evaluate and treat patients in treatment rooms; likewise a professor evaluates and teaches its students in class rooms.

We consider there is enough similarity between a hospital and a higher education environment to effectively adapt the RIM to satisfy the information requirements needed for the first goal defined in 1.3 - specify an information model.

The constructed information model (**Fig. 7**) is expressed using the Unified Modeling Language (UML), and is composed of three main classes: Entity, Role, Act and Infrastructure.

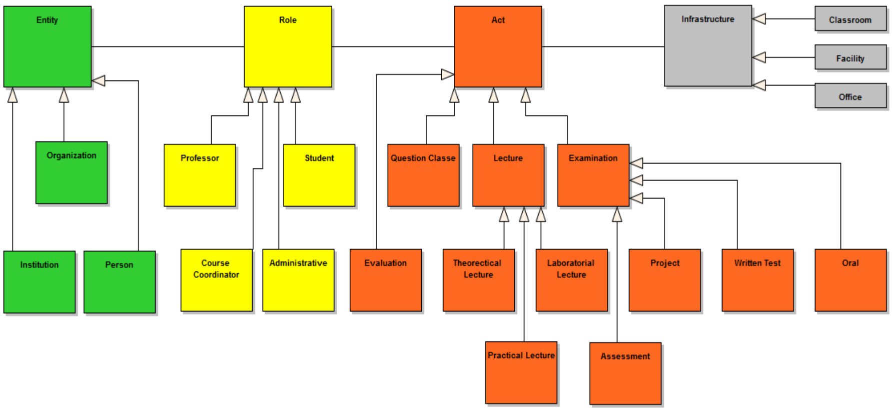

Fig. 7. Information model of a higher education institution

Entities are related to Roles, and through their Participations interact in Acts. An Entity represents some physical being that performs a function (e.g Organization and Institutions). A Role establishes the role that entities play and they participate in Acts. Participation expresses the context for an Act. An Act represents the actions that are executed and must be documented. An Infrastructure represents the physical environment where the Act is performed.

Following the studied higher education domain we identify four main roles **Fig. 7**: Student, being a person that frequents a university that is subject to evaluation; Professor, being a person that lectures course modules in a university; Course Coordinator, being a person that is responsible for planning and managing a course; Administrator, being a person responsible for the management of a higher education institution.

Step 2: Definition of the Monitoring Objects

A selection is made for the objects that must be monitored in real-time. These correspond to KI related to higher education students, and will be organized by KPI, KRI and KCI (refer to section 2.2).

The process of selecting indicators involved surveying techniques such as questionnaires directed to students and professors, student interviews, research on KI used by reference universities, and research done on KI by other authors [2, 10]. Following the research done on the subject, we define a set of base KI:

KPI: indicators that monitor students' performance in relation to established university goals.

1. KI1-Student course modules grade evolution;
2. KI2-Student average grade evolution, in relation to the number of enrollments and other students;
3. KI3-Average student grade, discriminated by course or course module;
4. KI4-Student grade discriminated by course module and course module evaluation component (e.g. test, projects, etc.);
5. KI5-Number of course modules passed;
6. KI6-Student weekly study hour report, discriminated by course module;

KRI: *indicators that monitor students' risk profile in relation to established control measures.*

7. KI7-Course module evaluation component submission/accomplishment;
8. KI8-Course module flunk risk;
9. KI9-Course module accomplishment rate;
10. KI10-Course conclusion time;

KCI: indicators that monitor the effectiveness of the university's control measures.

11. KI11-Student attendance, discriminated by course module;
12. KI12-Number of enrolled course modules, discriminated by student;
13. KI13-Student weekly study hour report, discriminated by course module;
14. KI14-Student grade requirement for approval at a course module;
15. KI15-Course module approval rate per academic term;
16. KI16-Student status;

The KI listed above allow monitoring student's progress through their study in higher education institutions, and contribute for the definition of a real-time activity monitoring model as defined in our goals. Indicators are constructed using a weighed formula calculation, applied to basic and derived indicators. Basic indicators are the direct result accessing a measure value M, and derived indicators are the result of the computation of basic or derived indicators. We will designate basic indicators as level 1 indicators I1, and derived indicators as level 2 indicators *I2.* **Fig. 8** displays a schematic representation of KI based on precedence derivation with weighed calculation. I1 and I2 are derived as follows:

$$I1 = \sum_{k=1}^{n} \mathrm{M_k W_k};\ \sum_{k=1}^{n} \mathrm{W_k} = 1;\ (1)$$

$$I2 = \sum_{k=1}^{n} \mathrm{I1_k W_k};\ \sum_{k=1}^{n} \mathrm{W_k} = 1;\ (2)$$

M = metric value; W = relative weight (%)

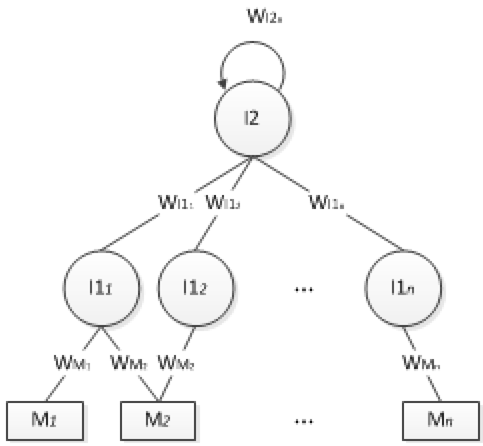

Fig. 8. Dendrogram representation of weighted indicator calculation.

Thresholds are defined to the listed indicators based on business rules and context of the system on which they are implemented. Thresholds are specific to the type of indicator group: in a benefit indicator (the bigger the measure the better) the threshold defines one or more lower bounds; in a cost indicators (the lower the measure the better) the threshold defines one or more upper bounds, and on-point indicators (the closer to a predefined value the better) in which a threshold defines one or more lower and upper bounds. The proposed KI are categorized as follows.

Benefit Indicators: KI1, KI2, KI3, KI4, K5I, KI9, KI10, KI11, KI15;

Cost Indicators: KI8;

On-Point Indicators: KI6, KI7, KI12, KI14, KI16;

A color scheme is defined with the colors *green*, *yellow* and *red* to aid visualization of indicators, according to their value and threshold points. *Green* represents indicators within an acceptable value range. *Yellow* represents values with slight deviance from the acceptable range, it signals that the entity or process that is being monitored needs attention. *Red* represents values with big deviance or with grave implication in the business process, requiring immediate attention and action.

Step 3: Dashboard Design

In this step the definition of the structure and display format of the dashboard is developed. The structure is conceptualized using the modeling tool Enterprise Architect and with recourse to Unified Modeling Language (UML) to develop a structural model containing the relationships, multiplicity, attributes and functions of dashboard components. The display format is conceptualized using mockups of dashboards applied in different contexts and regarding different user roles through the use of use cases. The design comes from an analysis of current dashboard solutions in the market, from guidelines proposed by authors in the area of presentation formats [8, 13] and dashboard modeling and design [1, 4, 5, 7, 12].

The diagram in **Fig. 9** depicts the monitoring model created for the monitoring process. The objects *Graphical Object, Template, Threshold, Indicator* and *Metric* represented in green are structural components of the dashboard.

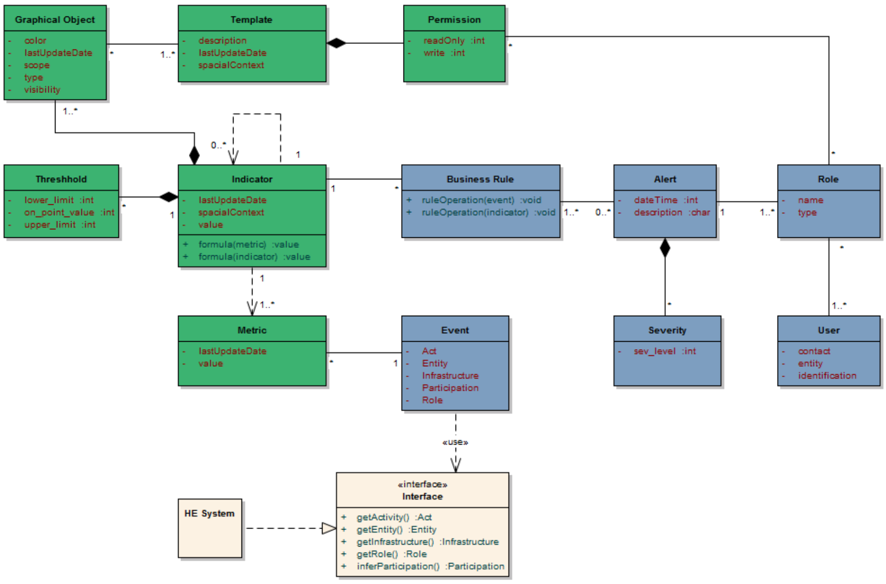

Fig. 9. Monitoring model discriminated by structural elements (green) and business elements (blue)

The objects Business Rule, Event, Alert, Severity, Role, User and Permission represented in blue are business components associated with the monitoring process that provide data and context to the dashboard.

Mockup design of the proposed dashboard interfaces are presented in below for student, teacher and course coordinator perspectives respectively.

Student Dashboard Mockups.

This section provides mockups of the proposed dashboard interface for the student profile. Each dashboard is displayed in a “window tab” to facilitate navigation and presentation of the different views.

The first dashboard (**Fig. 10**) displays indicators relative to a student’s current performance in enrolled classes. The dashboard displays information about the student profile (e.g. average grade, status and current year); a pie chart with the workload distribution on enrolled classes; detailed table of enrolled classes with information about evaluation components’ grades; a bar chart with the student’s lecture attendance percentage discriminated by class; a line chart with indication of the study hours reported each week discriminated by class; a table with the upcoming evaluation components (e.g. exams and projects); a text box displaying relevant alerts based on the student’s performance and profile.

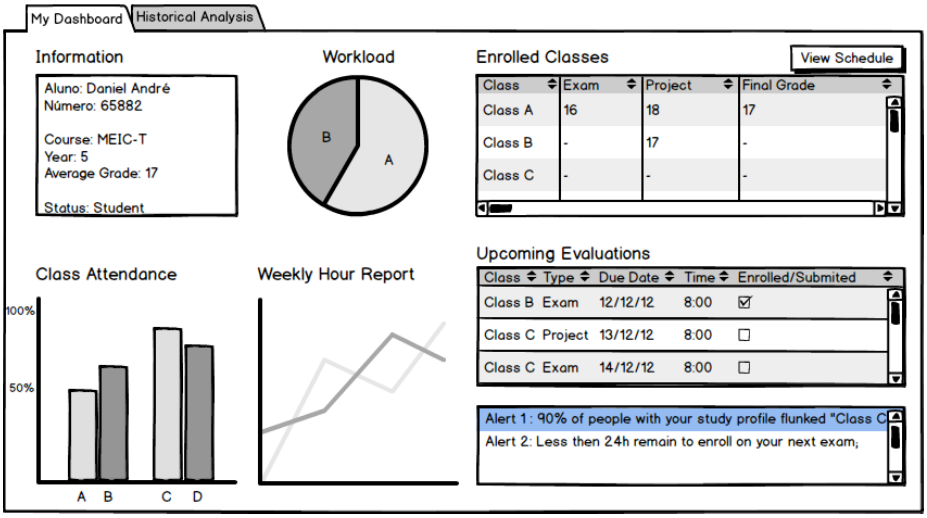

Fig. 10. Student dashboard displaying real-time performance on enrolled classes (current semester)

The second dashboard (**Fig. 11**) displays indicators relative to a student’s historical performance in his course, for analysis purposes. The dashboard displays information about the student’s profile; a table with the student’s course curriculum, displaying passed and failed classes as well as the associated grades, weights and dates of enrollment; a bar char with the number of enrolled classes and approvals per semester; and a line chart with the average grade progression discriminated by semester.

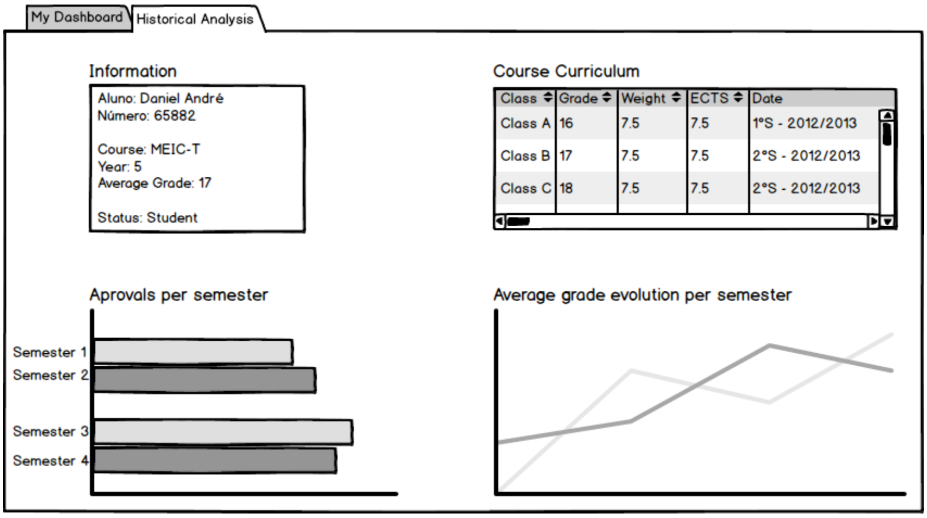

Fig. 11. Student dashboard displaying historical course performance (per semester)

Teacher Dashboard Mockups.

This section provides mockups of the proposed dashboard interface for the teacher profile, in which aggregated information about students' performance is displayed. Each dashboard is displayed in a "window tab" to facilitate navigation and presentation of the different views. In this particular case, a teacher has available one tab for each class he is responsible. The first dashboard (**Fig. 12**

Fig. 12) displays indicators relative to students' performance in the classes in which a teacher is responsible. The dashboard displays aggregated information about enrolled students; student attendance; a table with the list of students enrolled and associated indicators; charts with exam results; a pie chart with the rate of successfully submitted projects/homework; a chart with the average weekly study hours reported by students; a text box displaying relevant alerts based on the class's profile and student's.

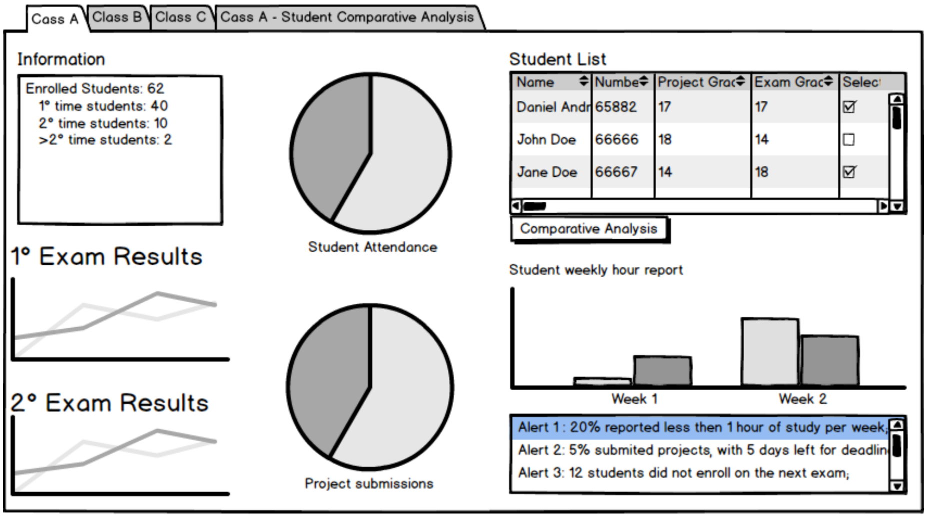

Fig. 12. Teacher dashboard displaying real time performance on lectured classes (current semester)

The second dashboard (**Fig. 13**) displays a comparative analysis between a set of students by correlating indicators relative to students' performance in the classes in which the teacher is responsible.

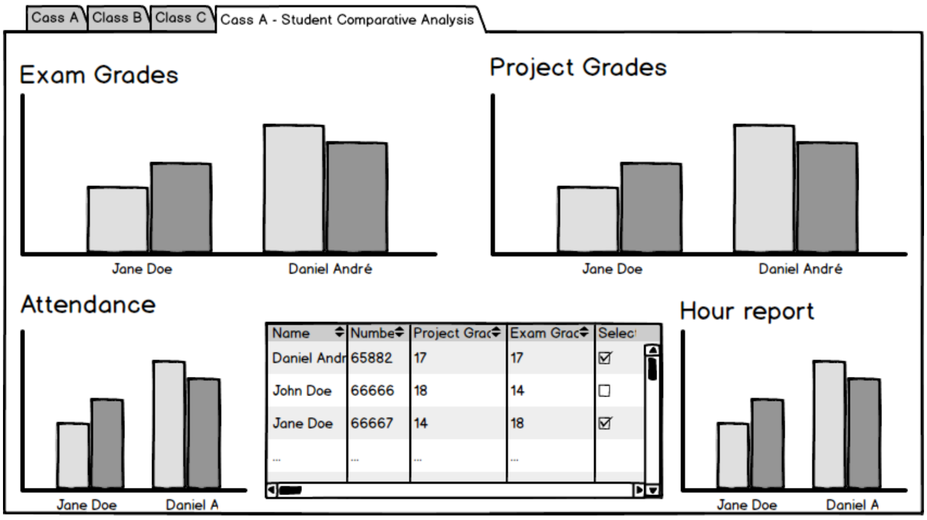

Fig. 13. Teacher dashboard displaying comparative analysis on enrolled students' performance

Lastly **Fig. 14** displays the result of a drilldown operation over a particular student in the previous dashboards (teacher perspective). This operation can be done by clicking on an individual student. Contrary to the other, this dashboard now only displays information relative to a single student performance.

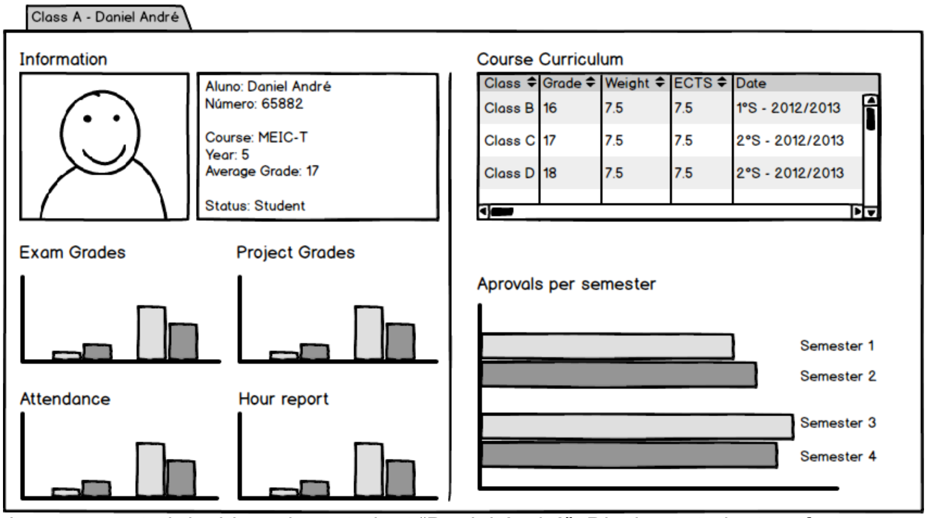

Fig. 14. Drilldown generated dashboard on student "Daniel André". Displays student performance regarding the class from where the drilldown originated, and general course performance.

Course Coordinator Mockups.

This section provides mockups of the proposed dashboard interface for the course coordinator profile, in which aggregated information about overall students' performance in the course and class is displayed. Each dashboard is displayed in a "window tab" to facilitate navigation and presentation of the different views. In this particular case, a course coordinator has available a tab that displays a comparative analysis of all the courses' performance with the possibility of drilldown on a particular course.

The first dashboard (**Fig. 15**) presents aggregated information about all the courses, displaying the number of enrolled students by year; a pie chart with the distribution of students by course; a table with the number of students by course; bar charts with the average grade, approval rate and attendance rate discriminated by course.

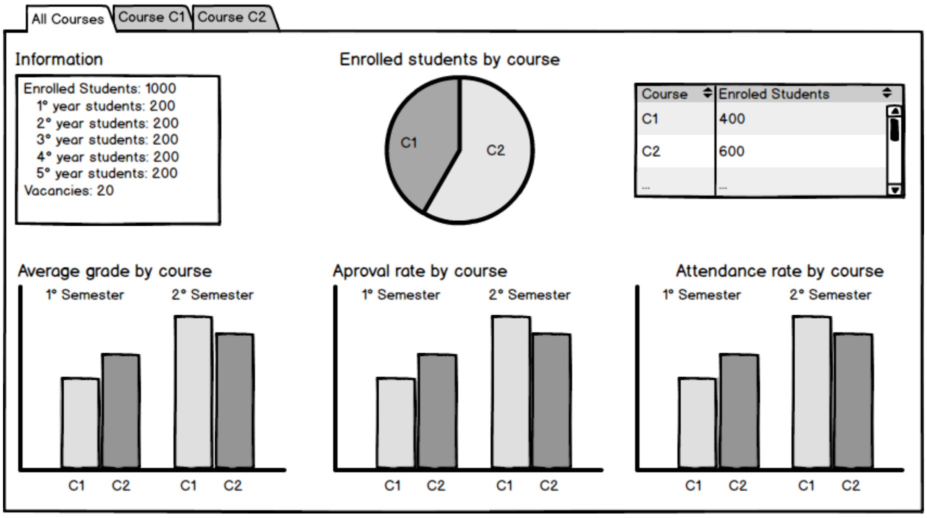

Fig. 15. Course coordinator dashboard displaying aggregated and concise information about each course (C1 and C2)

The second dashboard (**Fig. 16**) displays the result of a drilldown operation over a particular course. This operation can be done by clicking on an individual course. Contrary to the previous dashboard, this one now only displays information relative to a single course by presenting the performance of each class in that course. It displays: the number of enrolled students by year; a pie chart with the distribution of students by class; a table with the number of students by class; bar charts with the average grade, approval rate and attendance rate discriminated by class.

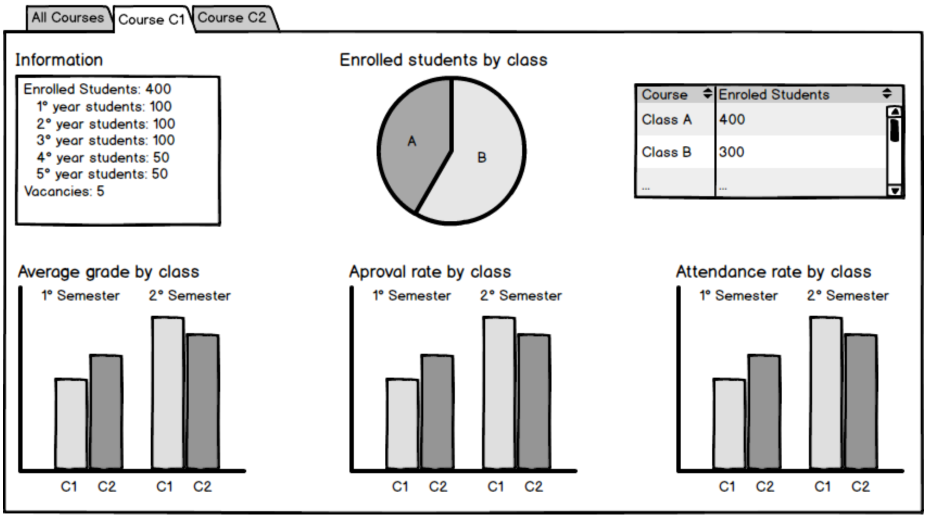

Fig. 16. Drilldown generated dashboard on a particular course (C1)

Step 4 & 5: Definition of Events and Presentation Rules.

In this step we define the events that are monitored to follow up the status of the selected KIs. Events are occurrences in time that record a specific activity in a given context. In this work events translate in a data update from database. Example of an event is, for instance, the publication of a grade in the final exam of the course module relative to a given student. In this case the event to be monitored would be the publication of the grade associated to a module, a student and an evaluation component that would then be used to update a KI in that context. This is accomplished through the use of an interface (**Fig. 17**) to extract data from a Higher Education System.

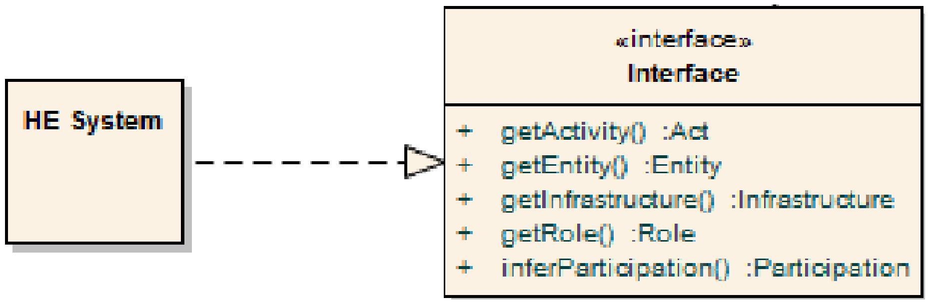

Fig. 17. Event capture interface based on proposed information model (Entity, Role, Participation, Act infrastructure)

The events monitored are defined in the information model, consisting in: Act, Entity, Infrastructure, Role, and Participation. Entities have Roles, which Participate in an Act. An Entity represents a physical being that performs a function (e.g Organization and Institutions). A Role establishes the role that entities play and how they participate in Acts. Participation expresses the context for an Act. An Act represents the actions that are executed.

The data flow starting from an event capture to the presentation of KIs is specified in **Fig. 18** presents the model for the monitoring process and data flow originating from the event capture.

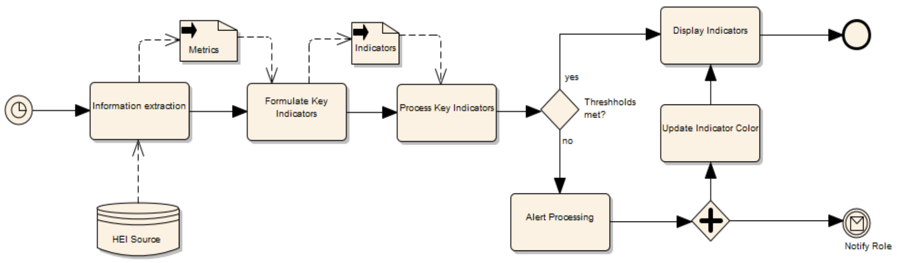

Fig. 18. View of the monitoring process and data flow of event capture and indicator display

4 Case Study: Instituto Superior Técnico FénixEDU

Instituto Superior Técnico (IST) is a higher education institution of Lisbon Tech, and is the largest engineering school in Portugal, with a strong focus on developing quality education and research in engineering, science and technology. In 2002 IST started to develop the FénixEDU project with the goal of developing an academic information system for higher education. Today this system is the basis for all academic processes at IST.

Research has shown that FénixEDU has some capabilities towards monitoring students' curricular progress, such as the display of indicators (listed in **Table 5**) and metrics (annex B). These indicators and metrics were extracted from the student area within the system. It also has available semestral Curricular Unit Quality reports (CUQ). CUQ are made via anonymous student electronic questionnaires available in the FénixEDU system. It displays performance indicators of course modules' teachers and activities such as student course frequency, teacher pedagogical performance, and course grade distribution.

Indicators	Description	Formula
Course grade average	Pondered average of all the course modules aproved	Sum (Weight x Classification) of each module / Sum (Weight) modules
Curricular year	Current curricular year of the student based on the number of approved modules	minimum (integer ((credits ECTS approved + 24) / 60 + 1) ; Nº of course years)
Approval rate by semester	Percentage of approved modules by semester	Number of modules approved / number of modules enrolled
Number of approved modules	Number of modules approved with a grade higher or equal to 10	Sum(approved modules)

Table 5. Indicators in FénixEDU available to students at IST

This system lacks, however, in terms of displaying the information, it is dispersed throughout several pages and a student cannot easily keep track of their curricular performance since there are no dashboards or any other page with consolidated information. CUQ reports are the only source of analysis, but these are only made at the end of each semester. IST is effectively blind for 6 months at a time, having no real time visibility over their students' progress.

FénixEDU will be used as a starting point for the development of the solution. The existence of student key indicators and the lack of a monitoring tool make it an ideal system to study the implications of the solution proposed by this work.

4.1 Use Case

This section makes use of the architecture defined in chapter 3 and presents an example of an application of a subset of the proposed indicators, displaying three KI types (benefit, cost, and on-point). A scenario described by creating KI and defining thresholds, description, values, granularity and types of display. These will be divided between student and teacher perspectives.

4.2 Student Perspective

Indicators in this perspective are characterized as having detailed information relative to a specific activity, and hence have the objective of monitoring. These perspectives allow analysis also allowing the monitoring of specific indicators in a given context. The following paragraphs present short application scenarios of benefit, cost and on-point types of indicators on the course module ICE (Introduction to Computer Engineering) relative to a specific student called 'John Doe'.

Class attendance indicator (ca).

The *class attendance* indicator refers to the percentage of classes that John Doe has attended. John has the possibility of comparing his attendance with that of his class, thus giving him the possibility to perform a comparative analysis of his performance. It is expected from John to attend at least 80% of lectures in ICE. Thus *class attendance* is defined as a benefit indicator, the higher the value the better, with a lower bound of 80%. Furthermore an additional bound is defined at 70% to differentiate between levels of severity: ca>80% with no severity level of green, corresponding to the expected value range; 60%< ca <80% equates to a severity level of yellow; ca <60% equates to a severity level of red.

Class Attendance	
Type	Benefit
Threshold	80%; 60%
Granularity	Day; Week; Semester
Display type	Percentage; Unitary

Table 6. Class attendance indicator properties for course module ICE

Fig. 19 below demonstrates a visual representation of the class attendance indicator using a barchart. John's attendance (bar in blue) is above class average (bar in red), so it can be concluded that when compared with his collegues John is performing well. However John is below the threshold of 80% (yellow line) defined in ICE for class attendance but above the 60% threshold (red line). This equates to an alert of severity level of yellow, which results in an alert being given to John of his underperformance relative to the class's established objectives. If John were to have an attendance percentage below 60%, an alert would also be sent to the class's teacher.

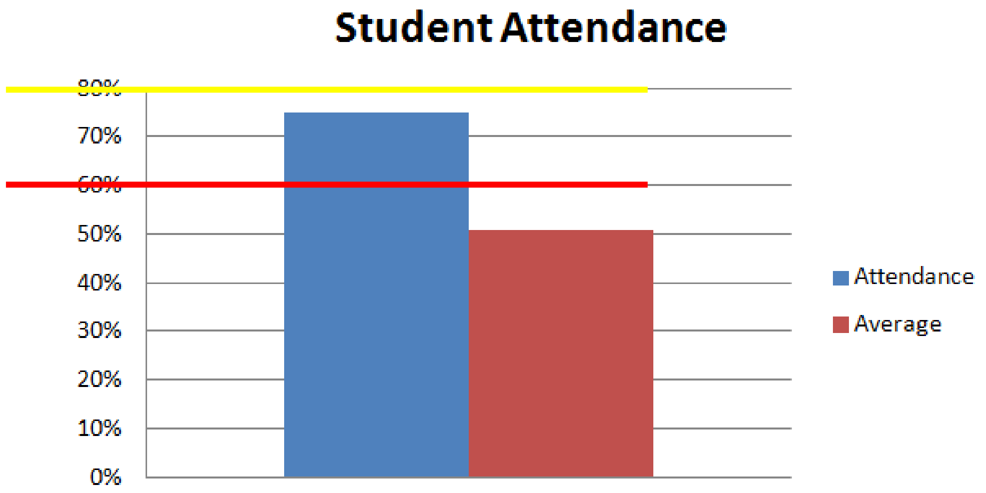

Fig. 19. Visual display of John Doe's attendance indicator in ICE, alongside with the attendance indicator of the class average

Study hour report indicator (shr).

The amount of hours of study reported by John Doe is represented by the *study hour report* indicator. This indicator is dependent on class syllabuses, and thus the expected hours of study from students vary depending on the class. *Shr* is defined as an on-point indicator with an on-point value of 'a' and an expected variance of 'b', where 'a' refers to the hours of study expected for a given class and 'b' to an hour range of acceptable deviance relative to 'a'. In this particular case John is being evaluated in ICE, which has an established value of 'a' of 11 hours and a value of 'b' of 1 hour. It is expected of John to study 10 to 12 hours weekly in the class ICE.

Hour report		
	Type	On-point
	Threshold	11h ± 1h
	Granularity	Day, Week, Semester
	Display type	Unitary

Table 7. Study hour report indicator properties for course module ICE

Fig. 20 below demonstrates a visual representation of the study hour report indicator using a barchart (bue rectangles) in conjunction with a line chart (red line). John's hour report per week is represented in the blue rectangles, and the class average is represented in the red line. We can verify that in the first 4 weeks John is underperforming in relation to the class average and in weeks 5 and 6 is overperforming. In relation to ICE's established objectives John is not performing as expected. It can be seen that John's hour report is always below or abbove the acceptable value range defined by ICE, and thus John receives an alert informing him of his low performance.

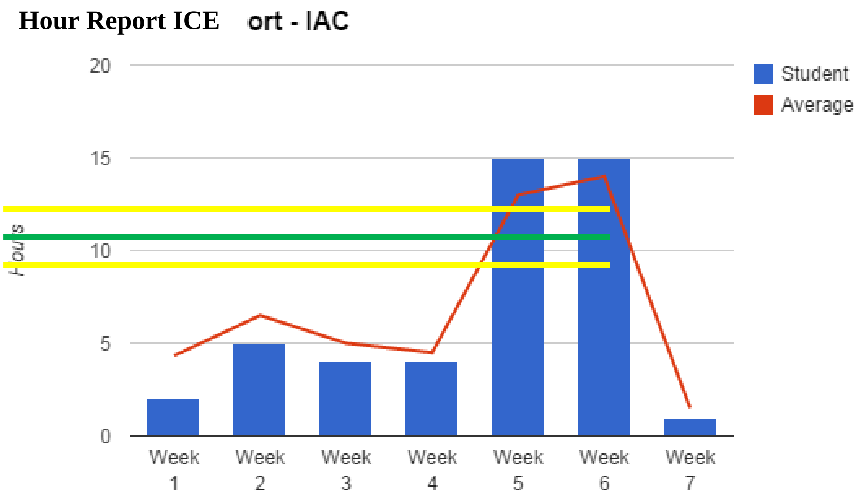

Fig. 20. Visual display of John Doe's hour report indicator in ICE, alongside with the hour report indicator of the class average

Course module flunk indicator (cmf).

The *course module flunk* indicator presents information on the likelihood John will flunk at ICE based on the control indicator *shr* shown on the previous scenario, the worse the *shr* the higher the *cmf*. It is expected that the number of flunks in a module is as low as possible, thus *course module flunk* is defined as a cost indicator, the lower the value the better. We define three value ranges (green, yellow and red) with thresholds set at 33% and 66%. Green if *cmf* < 33%, represents low risk of failing; yellow if 33% < *cmf* < 66%, represents a moderate risk of failing; red if 66% < *cmf,* represents a high risk of failing.

Course module flunk	
Type	Cost
Threshold	33%; 66%
Granularity	Semester
Display type	Color;

Table 8. Course module flunk indicator properties for students at ICE

Fig. 21 below demonstrates a visual representation of the *cmf* indicator using a barchart. John's control indicator *shr* from the previous scenario showed that he was underperforming, so the *cmf* indicator is updated accordingly, displaying a yellow color bar at 50%, preemptively alerting John that if hecontinues on this course he might fail his class.

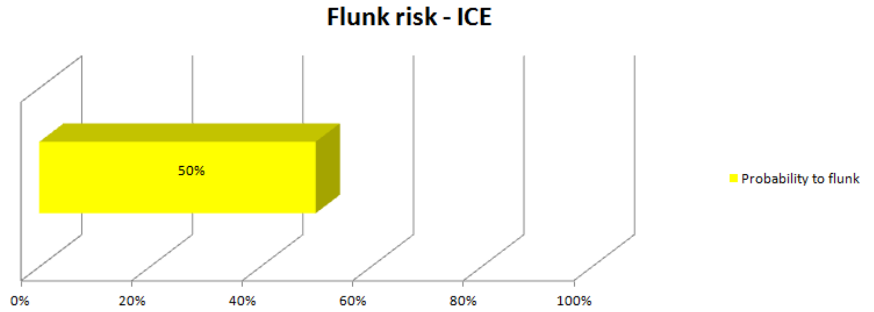

Fig. 21. Visual display of John Doe's course module flunk indicator in ICE

4.3 Teacher Perspective

Indicators in this perspective are characterized as having aggregated and concise information, which is typical of tactical and strategic perspectives. These perspectives allow analysis by comparing performance over different activities, while also allowing the monitoring of general indicators in each one. The following paragraphs present short application scenarios of benefit, cost and on-point types of indicators on the course module ICE (Introduction to Computer Engineering) given by a specific teacher named 'Jane Doe'.

Class attendance indicator (ca).

The *class attendance* indicator refers to the percentage of students that attend lectures. Jane established that in her class it is expected from students, in normal circumstances, to attend at least 80% of lectures. Thus *class attendance* is defined as a benefit indicator, the higher the value the better, with a lower bound of 80%. Furthermore Jane wants to be informed of students that attend less than 70% of her classes so she can take appropriate measures. An additional bound is therefore defined at 70% to differentiate between levels of severity: ca>80% with a severity level of green, corresponding to the expected value range; 60%< ca <80% equates to a severity level of yellow, indicating a slight deviance from the expected value range; ca <60% equates to a severity level of red, indicating a strong deviance from the expected value range.

Class Attendance	
Type	Benefit
Threshold	80%; 60%
Granularity	Day; Week; Semester; p/Class
Display type	Percentage; Unitary

Table 9. Class attendace indicator in class ICE

The graph in **Fig. 22** displays the visual representation of *ca.* The indicator is presented in a line chart, which is suited to follow the evolution of the students' attendance over the period of the semester. We can verify that the attendance percentage (represented in the blue line) is dropping as the semester progresses. Jane can view how the attendance in her class evolves over time. As soon as the attendance drops below 80% in the 5th class, Jane is alerted to the fact that the percentage of students attending her class is not according to plan. This allows Jane to preventively create new measures to increase the number of students in her class. When the value drops below 60% Jane is alerted, so she takes immediate action and drills down on the attendance indicator to check individual student attendance rates. She selects a subset of students with a low presence in her classes and takes appropriate measures to correct the situation.

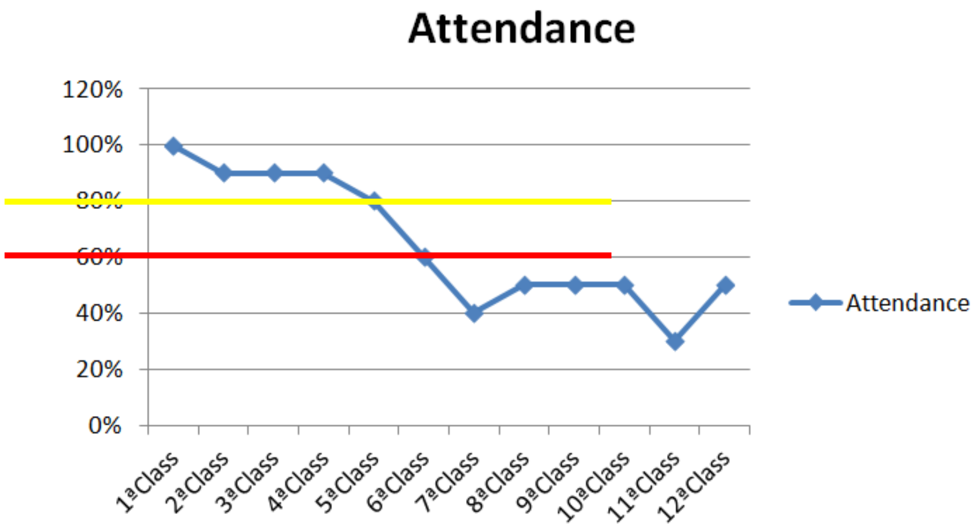

Fig. 22. Visual display of the class attendance indicator over the course of 12 classes in ICE

Study hour report indicator (shr).

The amount of hours of study reported by students is represented by the *study hour report* indicator. *Shr* is defined as an on-point indicator with an on-point value of ‘a’ and an expected variance of ‘b’, where ‘a’ refers to the hours of study expected for a given class and ‘b’ to an hour range of acceptable deviance relative to ‘a’. In the particular case of ICE we attribute ‘a’ the value 11 hours with a variance ‘b’ of 1 hour.

Hour report		
	Type	On-point
	Threshold	11h ± 1h
	Granularity	Day, Week, Semester
	Display type	Unitary

Table 10. Hour report indicator properties for course module ICE

The graph in **Fig. 23** displays the visual representation of *shr.* The indicator is presented in a line chart, which is suited to follow the evolution of the students’ hour report over the period of the semester. Jane has an overall view of the amount of hours ICE’s students are studying and can take appropriate measures accordingly. We can verify that all weeks on the exception of week 5 are not within the acceptable value range (area between the yellow lines).

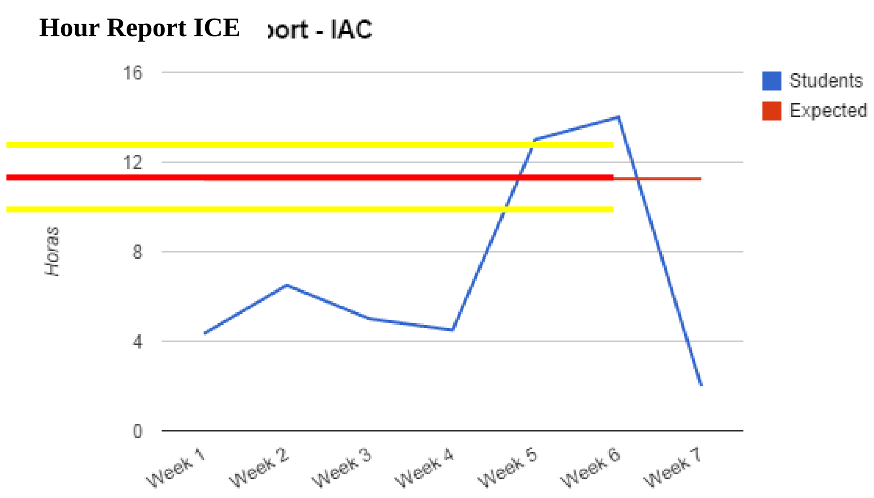

Fig. 23. Visual display of the hour report indicator over the course of 7 weeks

Jane has the possibility to roll up on the *shr* indicator on the class and time to perform a comparative analysis with other classes over the semester (**Fig. 24**).

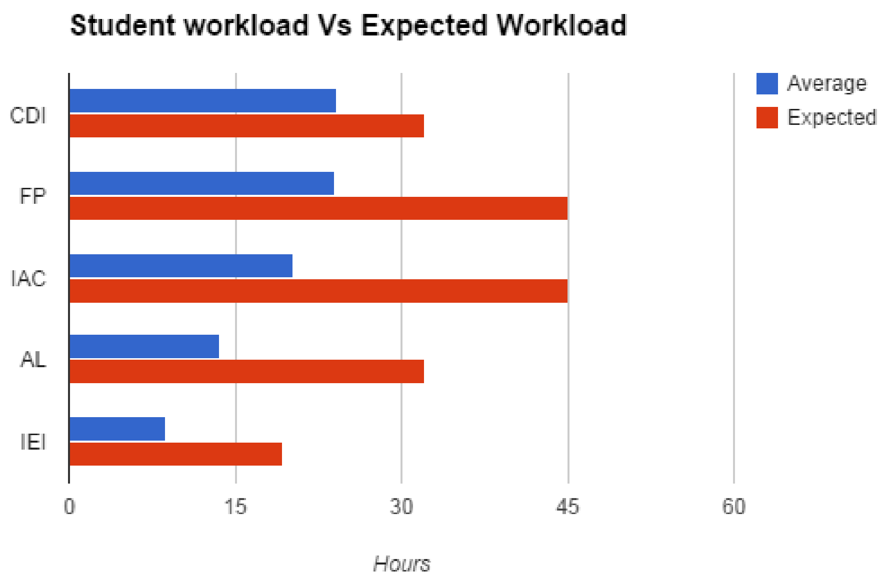

Fig. 24. Graph with comparative analysis between course modules on the *shr* indicator over a semester

Course module flunk indicator (cmf).

The *course module flunk* indicator presents information on the amount of students that are at risk of flunking a course module. *Cmf* is based on the control indicator *shr* shown in the last scenario, the worse the *shr* the higher the *cmf* and vice versa. It is expected that the number of flunks in a module is as low as possible, thus *course module flunk* is defined as a cost indicator, the lower the value the better, with an upper bound of 2%.

Course module flunk		
	Type	Cost
	Threshold	2%
	Granularity	Semester
	Display type	Percentage; Unitary

Table 11. Course module flunk indicator properties for course module ICE

5 Work Evaluation Methodology

The validation of this work is based on the design science research methodology following the seven guidelines defined in [20]: design as an artifact, problem relevance, design evaluation, research contributions, research rigor, design as a search process, communication of research. **Table 12** summarizes the seven guidelines.

Guideline	Description
Design as an Artifact	Produce a viable artifact in the form of a construct, model, method or an instantiation.
Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Research Contributions	Provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.
Research Rigor	Application of rigorous methods in the construction and evaluation of the design artifact.
Design as a Search Process	Utilize available means to reach desired ends while satisfying laws in the problem environment.
Communication of Research	Design science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

Table 12. Summarized description of the seven guidelines of design science research as described in [21]

The work addressed by this thesis will consisted in the creation of 3 artifacts, each following its own set of guidelines. These artifacts are: information model, monitoring model and a dashboard construct. Each will underwent a process of evaluation by the use of application scenarios in a case-study context, and by prototype implementation and validation with the aid of professionals in the area of higher education.

6 Conclusions

The research work allows the specification of a conceptual model to monitor the performance of higher education students. The model supports the management and monitoring of higher education activities by defining a dashboard interface as a means to display vital information to an organization and, as such, assumes the role of a personalized informational cockpit adapted to a user profile (teacher, student, manager). It features information presentation through key indicators (in a graphical form) and through alerting capabilities, allowing analysis, control and visibility over curricular activities.

Not only does this project aim at contributing with a technological tool specification, but also at helping students to create good planning, management and control habits in their curricular activities, thus increasing their performance in their curricular endeavor.

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ANNEX

A. Survey on academic management platforms in higher education institutions in the area of Lisbon (2013)

Name	Plataform
Faculdade de Arquitectura da Universidade Técnica de Lisboa	netP@ Portal de Serviços académicos
Faculdade de Medicina Veterinária	netP@ Portal de Serviços académicos
Faculdade de Motricidade Humana	netP@ Portal de Serviços académicos
Instituto Superior de Agronomia	Portal da Divisão Académica
Instituto Superior de Ciências Sociais e Políticas	netP@ Portal de Serviços académicos
Instituto Superior de Economia e Gestão	ISEG Aquila
Escola Nacional de Saúde Pública	Moodle
Faculdade de ciências e Tecnologia	CLIP
Faculdade de Ciências Médicas	Moodle
Faculdade de Ciências Sociais e Humanas	Intranet, Secretaria Virtual
Faculdade de Direito	Moodle, Secretaria Virtual
Faculdade de Economia	Moodle
Instituto de Higiene e Medicina Tropical	Moodle, IHMTWEB
Instituto Superior de Estatística e Gestão de Informação	ISEGI-ONLINE
Faculdade de Engenharia	Portal Académico
Faculdade de Engenharia	e-Serviços ao Cidadão Académico
Instituto Superior de Novas Profissões	Moodle, Secretaria Online
Instituto Superior Politécnico do Oeste	Moodle, Secretaria Online
Academia da Força Aérea	eLe@rning (moodle)
Academia Militar	Moodle
Escola Superior de Saúde de Alcoitão	Plataforma de eLearning
Escola Superior de Enfermagem de Lisboa	Área Academica
Escola Superior de Hotelaria e Turismo do Estoril	Moodle
Escola Superior de Saúde Ribeiro Sanches	Moodle, Secretaria Online
Instituto Politécnico de Lisboa	Portal dos Serviços Académicos
Instituto Superior Autónomo de Estudos Politécnicos	netP@
Instituto Superior de Ciências da Administra-	Moodle, Secretaria Online

ção	
Instituto Superior de Educação e Ciências	Moodle
Instituto Superior de Gestão	netP@, Moodle
Instituto Superior de Gestão Bancária	ISGB Online
Instituto Superior de Línguas e Administração de Lisboa	Campus Online
ISPA - Instituto Universitário de Psicologia Aplicada	e-Campus, Moodle

Table 13. Results of a survey made on academic management platforms used in higher education institutions in the are of Lisbon, Portugal (2013)

B. Survey on metrics available on FénixEDU in the student area.

Metric	Description
Classes enrolled	Number of course modules in attendance
Classes approved	Number of approved course modules
Final classes grades	Final grade in a course modules rounded to units
Course grade average	Average grade from all classes approved
Currivular Year	Year attending, in accordance with the number of approved classes
Project delivery date	Final date for the delivery of a project
Test date	Date for the realization of a test
Approval date by semester	Percentage of classes approved by semester
Weekly effort	Indication of weekly effort (in hours) for each class. This need to be filled by the student itself.
Submited files	Metadata associated to the submission of files (e.g. projects and homeworks)
Student Status	Indication on whether the student is on a scholarship, an alumni or working.

Table 14. Designation and description of metrics availabe in FénixEDU

C. Conceptual model for dashboard perspectives

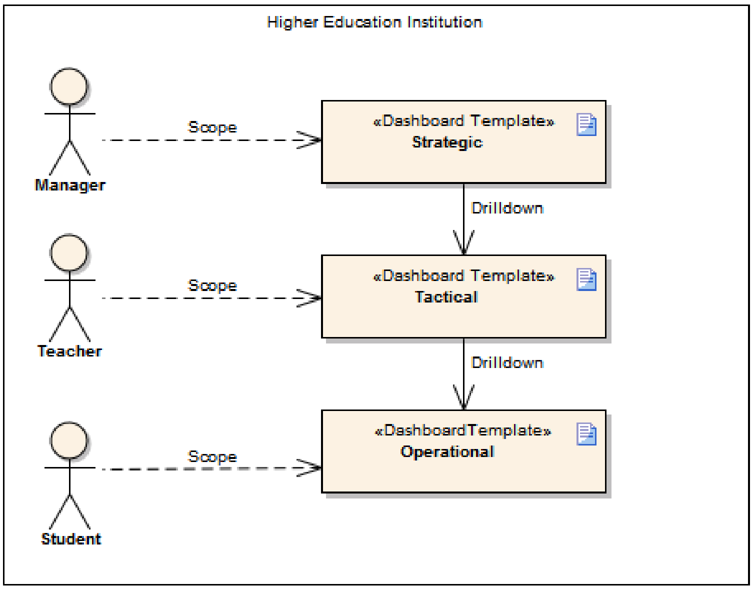


Fig. 25. Conceptual diagram model depicting different analysis perspectives and associated actors in a higher education context

D. Use case conceptualization for solution architecture

Use cases are described for three higher education actors, these being: student, teacher, and course coordinator. Each use case diagram presents the use cases related to a given actor within the system boundary (i.e. dashboard).

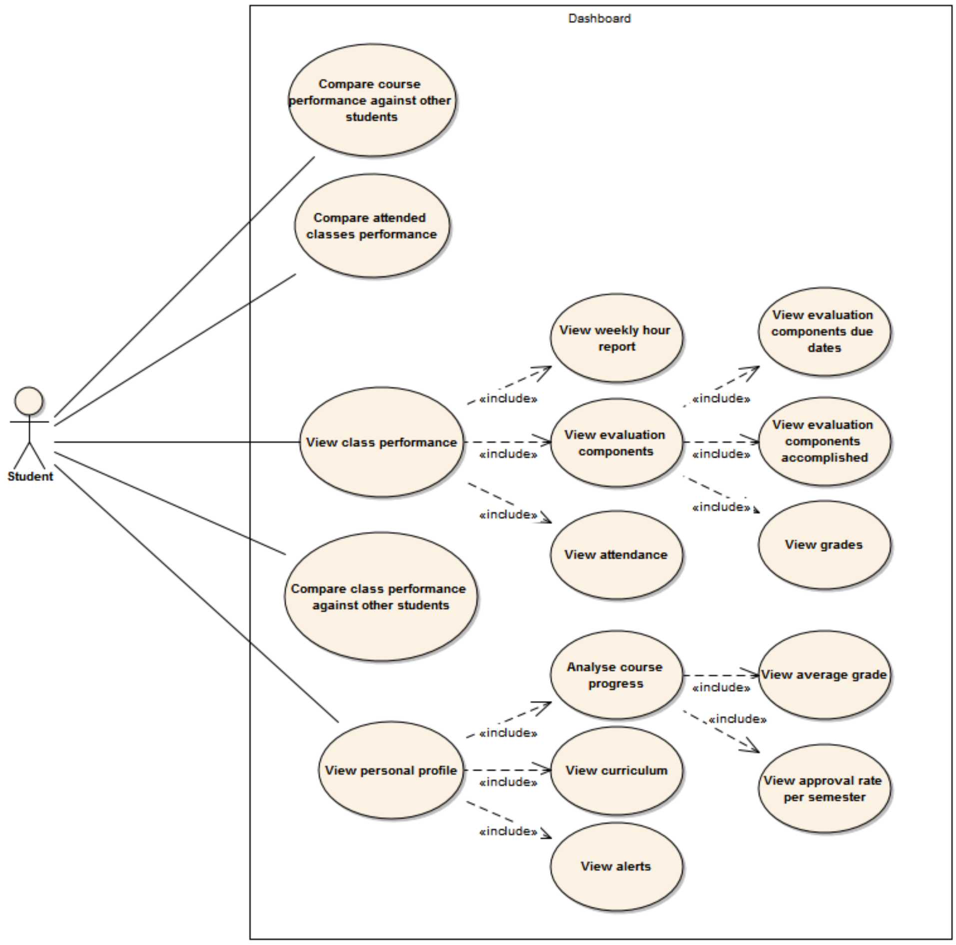


Fig. 26. Proposed use case diagram for the actor Student

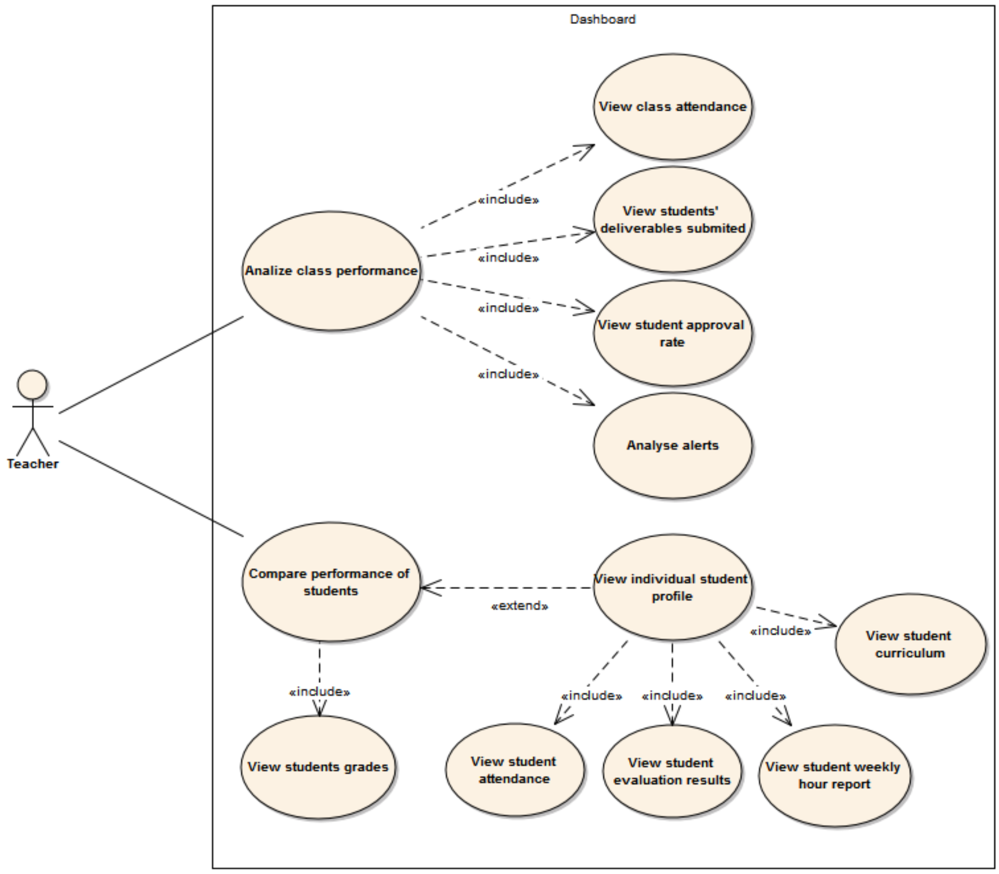


Fig. 27. Proposed use case diagram for the actor teacher

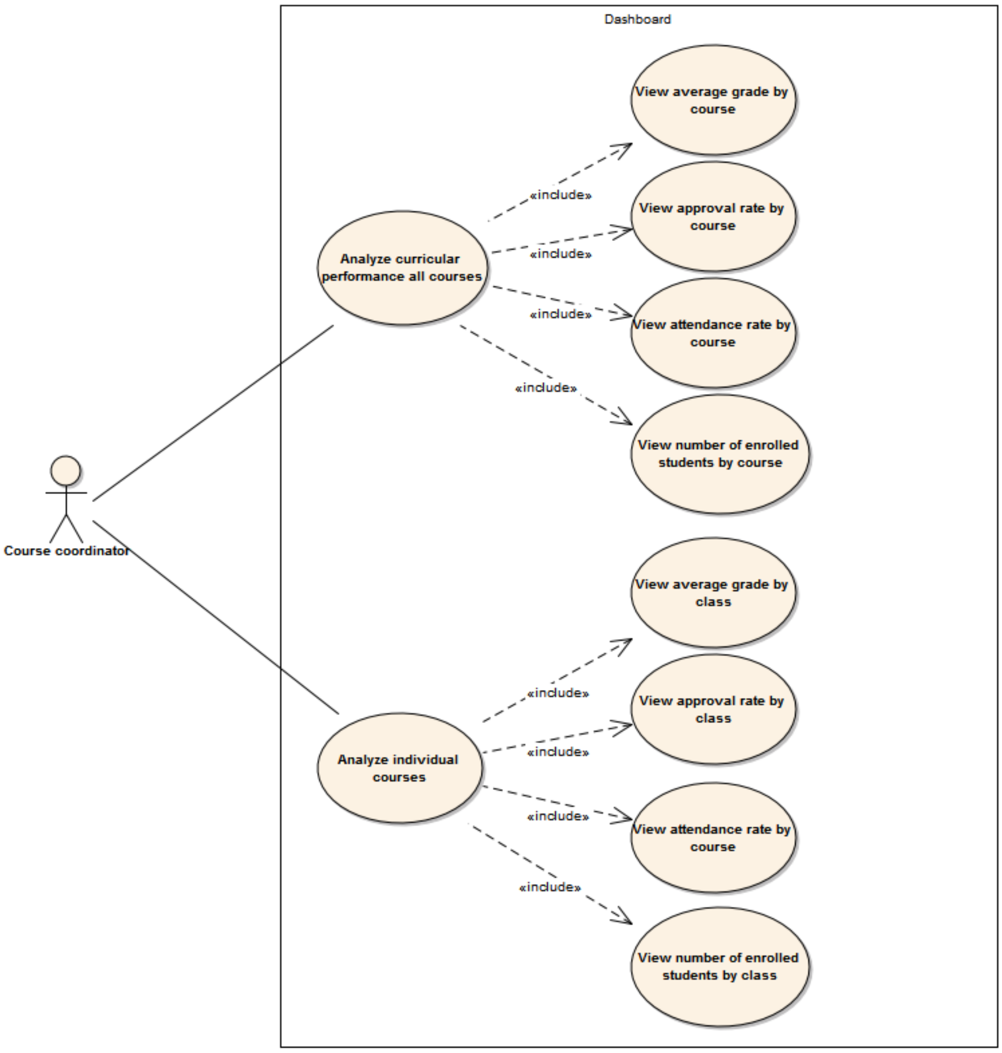
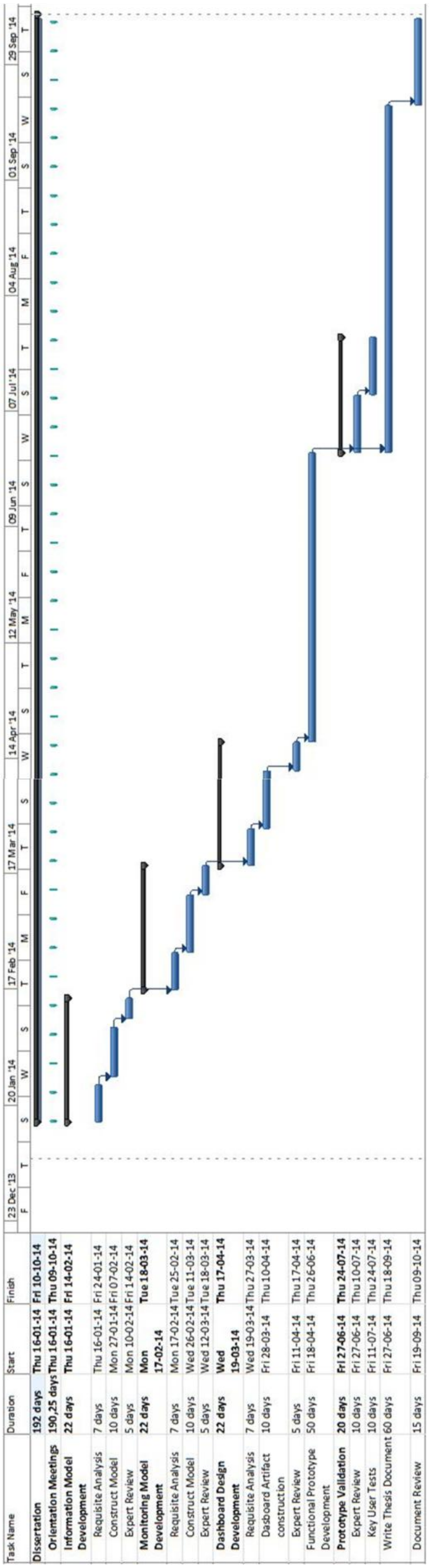


Fig. 28. Proposed use case diagram for the actor course coordinator

E. Work Plan



Task Name	Duration	Start	Finish
Dissertation	**192 days**	**Thu 16-01-14**	**Fri 10-10-14**
Orientation Meetings	**190,25 days**	**Thu 16-01-14**	**Thu 09-10-14**
Information Model Development	**22 days**	**Thu 16-01-14**	**Fri 14-02-14**
Requisite Analysis	7 days	Thu 16-01-14	Fri 24-01-14
Construct Model	10 days	Mon 27-01-14	Fri 07-02-14
Expert Review	5 days	Mon 10-02-14	Fri 14-02-14
Monitoring Model Development	**22 days**	**Mon 17-02-14**	**Tue 18-03-14**
Requisite Analysis	7 days	Mon 17-02-14	Tue 25-02-14
Construct Model	10 days	Wed 26-02-14	Tue 11-03-14
Expert Review	5 days	Wed 12-03-14	Tue 18-03-14
Dashboard Design Development	**22 days**	**Wed 19-03-14**	**Thu 17-04-14**
Requisite Analysis	7 days	Wed 19-03-14	Thu 27-03-14
Dasboard Artifact construction	10 days	Fri 28-03-14	Thu 10-04-14
Expert Review	5 days	Fri 11-04-14	Thu 17-04-14
Functional Prototype Development	50 days	Fri 18-04-14	Thu 26-06-14
Prototype Validation	**20 days**	**Fri 27-06-14**	**Thu 24-07-14**
Expert Review	10 days	Fri 27-06-14	Thu 10-07-14
Key User Tests	10 days	Fri 11-07-14	Thu 24-07-14
Write Thesis Document	60 days	Fri 27-06-14	Thu 18-09-14
Document Review	15 days	Fri 19-09-14	Thu 09-10-14