Dynamic Quality Evaluation in Higher Education

Silvia Gaftandzhieva [1], Rositsa Doneva [1], George Totkov [1]

[1] *University of Plovdiv "Paisii Hilendarski", 24 Tzar Assen Str., Plovdiv, Bulgaria*

Abstract **– The paper aims to propose, investigate and test suitable means for automation of the processes for dynamic quality evaluation of objects in a given subject area. On the basis of the theoretical study a number of conceptual and computational models are proposed. In consequence, the architecture of a software system for dynamic quality evaluation is defined and a corresponding software prototype is built over an existing university information infrastructure. General models are applied for dynamic quality evaluation of different objects in the field of higher education.**

Keywords **– Accreditation, Automated Quality Evaluation, Quality Evaluation, Higher Education.**

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Corresponding author: Silvia Gaftandzhieva,
University of Plovdiv "Paisii Hilendarski", 24 Tzar Assen Str., Plovdiv, Bulgaria
Email: sissiy88@uni-plovdiv.bg

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1. Introduction

Improving the quality of education is an important task for any educational institution. The discussed aspect of quality assurance and evaluation in higher education (HE) is the need for automation of its related processes. The use of automated tools in quality evaluation (QE) is the only possible manner to use effectively and in full degree all the data that have been collected and stored in electronic format during the educational process. It is essential that regardless of the needs for HE quality evaluation, no matter whether for internal or external evaluation, or for HE quality assurance and improvement, it is based on the respective criteria and regulatory procedures. Usually such criteria systems are very detailed and include a large number of evaluation criteria. The quality evaluation, applying such standards, requires the collection, analysis and interpretation of a huge amount of data to objective evaluation. Another important point, to which researchers are not paying enough attention, is that these systems require QE in HE to be carried out periodically and to reflect the processes' results of states of objects in different time periods (dynamic QE - DQE). DQE requires dynamically collecting, analysing and interpreting a huge amount of data for different aspects of HE related to: learning materials used; infrastructure; learning environment; tools of communication; student assessment system; flexibility and adaptability of the learning process; teachers' qualification and others.

The complexity of DQE systems is an additional argument for seeking solutions for automation of activities and procedures for QE. Similar automation is inconceivable without a well-functioning university information infrastructure. In this direction it poses a number of problems associated with the need to propose adequate process models for DOC, incl. extraction and processing of data from different information systems, which are often based on a different server, operating system, communication platform, database (DB), etc. These problems are essentially related to the need of creation and exploration of common conceptual and computational models of DQE systems, incl. tools for the integration of heterogeneous information systems and large datasets in relevant subject areas.

The paper aims to propose, investigate and test suitable means for automation of the processes for dynamical quality evaluation of objects in a given subject area, especially in higher education.

2. Literature Review

Worldwide, there are a lot of studies, organizations, initiatives, criteria and standards related to the quality of HE. In order to provide an overview and analysis of the field, the section presents a study of the general theory, existing organizations, models, standards and systems for quality assurance and evaluation and software tools for their automatization.

2.1. Organizations and standards

A globally recognized approach to quality assurance in HE is using complementary systems from internal and external forms of monitoring and evaluation carried out under standardized rules, methodologies and procedures. Worldwide, a number of specialised independent institutions are involved with the development of standards, specifications and guidelines for QE. As a result of the collaborative work of ISO, ICE and CEN, a number of standards related to the quality of learning and education have been established, incl. ISO/IEC 19796-1: 2009, ISO/IEC AWI 36000, ISO/IEC 19788-5: 2014, ISO/IEC 19788-2: 2012. There are many leading organizations that evaluate and give accreditation of programs and universities (ABET, EFMD) and promote excellence in HE and cooperation between institutions (INQAAHE, ICDE, Quality Matters).

After the signing of the Bologna Declaration in 1999, there was a significant increase in the importance and the role of QE procedures for HE in Europe. During the meeting of the Ministers of Education (held in Bergen in 2005) standards and guidelines for QE in HE were accepted [1]. The document contains standards and guidelines for internal quality assurance within HEI, European standards for external quality assurance of HE and standards for agencies to provide external quality. The standards and guidelines have been revised at the Ministers' Conference held in 2015 in Yerevan [2]. Within the overall policy of the European Union for the development of e-learning, the meeting in Bergen promotes several European and national initiatives related to the evaluation and improvement of the quality of e-learning and distance learning (DL) (incl. organizations as EDEN and EFQUEL). In accordance with the priorities and the policies of the Bologna process related to quality assurance of HE, independent assurance agencies for QE in HE operate in almost all European countries (Bulgaria - NEAA, UK - QAA, ODLQC, etc.).

2.2. Methodologies and models

There are a number of models for QE of objects in the field of HE: Learning process [3, 4], Specialty [5], Curricula and programs [6], LMS [6, 7], E-Learning [8, 9, 10, 11], Distance learning [12, 13], Institutions [5, 14, 15, 16], etc.

The considered models and methodologies for QE allow evaluation of objects of HE (university, faculty, specialty, etc.) from different perspectives. The models are built on a hierarchical basis. They contain a number of levels representing components/elements of the object (called spheres, criteria, indicators, etc.) that can be monitored in order to form a complex grade of the object. The evaluation of each indicator is based on the appropriate norm which is based on the appropriate criteria. Specifying the norm for comparison in a number of presented methodologies for QE is omitted or implicit. A typical case in the description of the indicator is "mixing" of the description of the object characteristics and the norm. In some cases it makes difficult the formulation of precise expert evaluation – e.g. in cases where the same characteristic implicitly is "included" in a number of indicators, each of which has a different norm and function for evaluation.

2.3. Automated quality evaluation

There are a lot of studies related to (self-)evaluation and quality management in HE with the automation of the relevant procedures.

The quality system of the University of Graz, Austria [17] generates a huge amount of data for quality monitoring. Information systems that collect statistics data play the central role in the system.

A web application for monitoring of academic performance in real time, according to the Baldrige criteria was developed in Indonesia [18]. The application is based on the business intelligence technology and service-oriented architecture. It uses web services for integration, extraction and collection of data from different sources - academic system, LMS, students system, research system, public services system, etc.

A web-based system COMPASS [19] was developed at the University of Plovdiv "Paisii Hilendarski". The criteria system is modelled by the tree structure, the root of which is the procedure of evaluation/accreditation. The final evaluation report and the accompanying evaluation forms that present the grade of each member of the expert group are automatically generated by the system.

The tools discussed imply the evaluation in a fixed model. The automated QE in HE suggests creation of a system that supports different models and allows:

- Conceptual modelling of methodologies for DQE of objects;
- Management and implementation of modelled methodologies for evaluating objects;
- Automated dynamic data collection for methodologies applied;
- Dynamic (self-)evaluation on a specific methodology based on data collected automatically.

A moment that must be noted is that QE of object in most cases has to be conducted in a very limited time; usually at or immediately after the period for which the evaluation will be conducted. Thus, activities for QE related to the collection and analysis of data for the object state from prior periods are difficult or impossible to be implemented.

3. Methods

The analysis conducted in section 2 allows to conclude what are the elements and sub-processes associated with the general model of a process for quality evaluation.

3.1. Model of a Process for Dynamic Quality Evaluation

Fig. 1. presents a general model of a dynamic process for QE of object. The dynamic of the process is presented with opportunities for changing the context and the methodology for QE of the object as a result of the accumulation of new information resources and conducting procedures for QE in different methodologies.

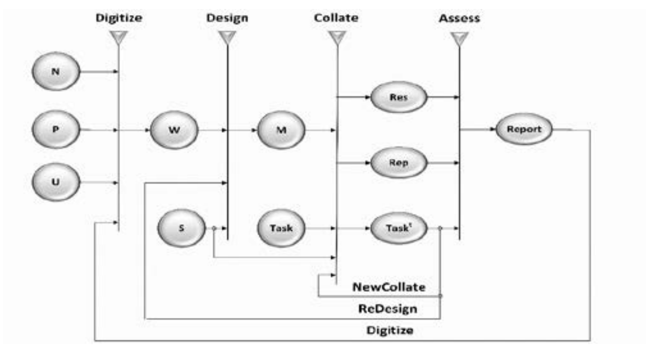

Figure 1. Model of a dynamic process for quality evaluation of object S

The evaluating object S can be an activity, system, procedure, product or subject in any subject area.

Norms, criteria, specifications and standards (N) are in the form of unformalised documents for QE on object S following different methodologies, methods and ways for organization of evaluation processes.

The users' requirements U and the best practices P are not formalized in almost all cases. U and P are not "obvious" elements of QE systems, although they are analysed, reported and taken into account when creating and using the methodology M for QE of S. Their separation as independent elements allows every change to be reflected by system of QE based on a general model from Fig.1.

The creation and the use of repositories W for storing information resources in electronic or conventional format is necessary preparatory stage of QE ($Digitize$). As a result of its conduction it can be assumed that the context of QE on S is digitised before the actual process for QE is starting and it is updating periodically. The result of QE process and accompanying documentation are becoming part of W.

The methodology M for QE of S is developing according to its nature and on the basis of the context C, represented in W with the various information resources. M includes options for the process for QE of S, accompanied by conditions and ways for continuation or completion of QE. M includes both elements of accepted specifications and standards for QE and elements of systems for quality management of institutions operating in the evaluation field SD. The logic of the different options, incl. requirements of the act of adopting the results of QE procedure, ways of their formatting, publishing, archiving, distribution, etc., is modelled later with the introduction of $Task^{\tau}$.

Experts in SD take part in the process of collecting and creating documents related to the QE of S (stage $Collate$). $Task$ for QE of S contains a schedule of activities and indicates the time period T (consisting of one or more non-intersecting intervals) from the life cycle of S for which the QE will be made.

The results of $Collate$ prepared by the $Task$ on the basis of the methodology M are in the form of a report analysis (Rep) and accompanied by Res – a set of supporting documents (analyses, reports, tables, etc.) related to the quality of different characteristics of S. Another result is $Task^{\tau}$- new task that eventuality will repeat the $Collate$ with a new time schedule.

The collection of data and supporting documents must be organized well before the start of the sub-process $Collate$ (start of a specific procedure for QE of S). In cases when such evaluation of S is not planed in advance, collection of data and supporting documents for previous time periods may not be possible. Therefore, when designing an ASDQE, **special attention should be paid to the creation of means for periodic collection and analysis of data relevant for different time periods that later could be used in the creation of documentary evidence for objects**.

The assignment $Task^{\tau}$ suggests taking one or more of the following decisions:

A. The process for QE of S to finish after end monitoring ($Assess$) of Rep and Res with the result $Report$, which will be recorded ($Digitize$) in W;

B. Reformation of methodology $ReDesign$ considering both $Report$ and revised (possibly) context incl. S, N, U, P and W;

C. After a certain time period restart ($NewCollate$) of the $Collate$ procedure on a new task with generation of more Rep and Res referring to the QE of S taking into account (or not) changes in S and W.

Periodic changes in methodology M have to be done in practise. The procedure for updating ($ReDe-sign$) is activated as a result of the monitoring ($Assess$) or in connection with the introduction of new elements related to S and its context C. The introduction of the $Task$ element in the general model in Fig. 1. gives a number of advantages in its computer implementation. In particular, a more elegant way to solve the problem for DQE of S **in different subsets of rules and criteria of M, ways of distribution and conducting relevant activities by expert groups of evaluators at set time periods.** In this way, ASDQE could start **automatically to "collect" the necessary documentary evidence** and to produce a number of reports $Report$ with automatically generated sets of documents at each time point $t_1, t_2, \dots, t_n$ of T. In this case, an important feature for the actuality of each produced document is the time point when it was created.

The final report Rep for QE of S is accompanied by appendixes Res, which support the analyses and conclusions of the main report, i.e. $Report = Rep \cup Res$.

The model of Fig. 1. does not include users, e.g. experts with different roles and functions. Although the organization of the QE process is not reflected in Fig. 1., in the creation of a computational model of DQE and in the formulation of functional requirements for the ASDQE this important element is taken into account (see 3.3).

3.2. Model of a system for DQE

Fig. 2. presents all objects, conceptual and computational models, stages and workflows which should be elements of the ASDQE.

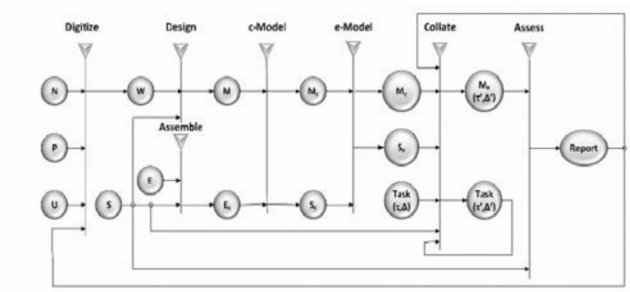

Figure. 2. Objects, models, procedures and workflows in ASDQE project

When creating a computational model S_e of an S object, whose quality will be evaluated by automatic means, the following two scenarios should be considered:

H1. For the evaluating object S are not available any information data, DB and tools for their processing other than W;

H2. For S similar means are set up (incl. DB and processing tools), including opportunities for using the QE procedures for various aspects of S.

In the case of H1, the classic way of creating information resources for S in the form of digital data, is organizing and conducting surveys for relevant aspects and elements of S among users or experts, summarizing, analysing and dissemination of results. $Survey(S)$ denotes the set of information resources in W, containing a package of "raw" and processed results that can connect with S.

In the case of H2, the creation of the computational model S_e of S is preceded by an analysis of the information infrastructure E of the institution within which S functions. The analysis ($Assemble$.) aims to identify and extract available in E data structures of objects (IS), processes (Pr), resources (R) and software tools for their automated processing ($Tools$), related (directly or indirectly) to S. Thus formed information context for $\boldsymbol{S}$ in $\boldsymbol{E}$ is denoted E_s.

In terms of both hypotheses the information context of S at an institution usually needs to be adapted and developed in order to create conceptual models S_c and M_c of S and M (see Fig. 2.), suitable for adequacy using of the methodology M for QE of S and for the effective implementation of its computational M_e

Elements of $E_s = < IS, Pr, R, Tools, S_0 >$, which may be used in the design and construction of a computational model S_e of S (as a result of $e - Model$) are identifying in creating S_c. The conceptual model S_c can be presented as follows: $S_c = S_c^f \cup S_c^a \cup S_c^n$, where S_c^f are conceptual models of tools from E, which can be used for S_e, S_c^a is the set of conceptual models of software tools needed for S_e (designed on the basis of adaptation of existing resources from E), and S_c^n are conceptual models for S that can be developed. S_c^a and S_c^n are the result of the process of conceptual modelling. Another option for solving the problems associated with computational model of S, is their complete or partial realization in the computational model M_e of M. Such a solution has the disadvantage that M_e is dependent on the further development of S_e.

M_c denotes the conceptual model of $\boldsymbol{M}$, created in the context C for QE of S. It should include elements as follows:

- model of evaluating areas/aspects of S in M, presented as nodes in a tree data structure and mechanism for QE;
- model of $Report$;

- model and mechanism for describing data of S and its aspects in the form of information resources and the attachment to subsets Res and Rep of $Report$.

Each (semi)evaluation of the quality of an object S is based on an examined set of characteristics of S. Composite indicators (criteria) and elementary indicators can be connected by relations of the matrix or hierarchical type. When creating models for QE of S the complexity of the respective indicator is determined depending on the complexity of characteristic or aspect of S. Usually, quality criteria submit certain terms of evaluating aspects (elements, conditions, results etc.), referring to the object S in a certain norm/ criteria. With each quality criteria is associated a measure by which in the context C determines the extent of compliance of the states and/or results related to S. The reporting of the level of compliance may be based on quantitative measures in appropriate measurement scale or expertise measurements. The overall quality evaluation of assessment on S is obtained on the basis of a complex grade Q based on a set of finite number of quality criteria $K = \{K_1, K_2, \dots, K_n\}$, each of which has its own measurement norm or comparison. Q_i denotes the compliance degree (Q_i) of criteria (K_i) of methodology M on L_i norm.

The tree structures a suitable math by means of which the hierarchy system of aspects $K = \{K_i: i = 1, 2, \dots, n\}$ of the object S, measured according to a methodology M can be modelled. $Tree\,(M, S)$ denotes the tree structure where the first element of M_c. $V = \{v_1,\ v_2, \dots, v_n\}$ denotes the set of nodes of $Tree\,(M, S)$, corresponding to the indicators $K_1,\ K_2, \dots, K_n$ of M, and with $Q = \{Q_1,\ Q_2, \dots, Q_n\}$ – the set of functions for quantitative or an expert measurement of the relevant quality criteria $K_1, K_2, \dots, K_n$, according to norms $L_1, L_2, \dots, L_n$. In general, the calculation scheme for the value of $Q_i = \{\,Q\,(K_i, L_i),\ i = 1, 2, \dots, n\}$ may be performed in a particular way, e.g. - functions for the composite indicator to be calculated on the basis of the values of the functions of their component indicators.

The standard case of formatting $Report$ is the preparation of (hyper)text document Rep, accompanied by a number of appendixes Res. In practice, supporting documents are cited by Rep and presented in the form of hard copies - Appendixes. There are two kinds of evidence:

D1. Electronic information resources located in the repository W (or E) in the form of text documents, spreadsheets, graphics, etc., which may be the result of data processing for S with software tools.

D2. References (links) to electronic information resources that are not located in W or E.

Further, $\wp$ denotes the space of information resources of type D1. The elements of $Report$ refer to the criteria system $K = \{K_i: i = 1, 2, \dots, n\}$ of M for QE of S, represented by the tree structure $Tree(M, S)$. On this basis, the structure can be used as a tool for the annotation of resources - elements of the $Report$ as follows. Let G is a subset of $K_1, K_2, \dots, K_n$ We will say that the Z resource is relevant to G, if Z contains information related to each element of G.

Definition 1. Let $Z \in Report$. We will say that ***Z* is annotated by *G*** if G is the maximum subset of K to which Z is relevant.

Definition 2. Let $Z \in Report$. We will say that ***Z* is a suitable annotation for the node *v*** of $Tree\,(M, S)$ if there is a subset $K_{j_1}, K_{j_2}, \dots, K_{j_d}$ $(1 \leq\ j_1 < j_2 \dots < j_d\ \leq n)$ of M criteria, which annotates Z and the node v is the predecessor of nodes $v_{j_1}, v_{j_2}, \dots, v_{j_d}$ (corresponding to $K_{j_1}, K_{j_2}, \dots, K_{j_d}$), located at the lowest level in $Tree(M, S)$.

It is easy to see that if resource Z is relevant to non-empty subset of K, it shall be annotated by only one a subset of K, therefore it is appropriate annotation for just a node of the $Tree(M, S)$. It is natural to assume that:

P1. Rep document, representing an overall QE of S on the methodology M, is relevant to K, therefore Rep is a suitable annotation of the root of $Tree(M, S)$. In practice, Rep is a hypertext document, the pages of which are annotations for nodes of $Tree(M, S)$;

P2. Each resource from Res is relevant to a non-empty subset of K; i.e. every element of Res is a suitable annotation for just a node of $Tree(M, S)$.

All resources of $Report$ can be uniquely "distributed" to nodes of the $Tree(M, S)$, which are suitable annotations. The $Report$ creation is annotating the nodes of the $Tree$ with adequate information resources. The adequacy of the information resource is determined by the content - the degree of compliance of the content and the actuality of the time period that it concerns. The actuality of the information resource r, attached to the node v of $Tree\,(M, S)$ is determined by its relevance to all its sub-indicators – components, i.e. if $Tree\,(M, S, v)$ is a subtree of $Tree\,(M, S)$ with node v the actuality of r is set in a tree structure $Tree\,(M, S, v), T(r, v) >$, where $T(r, v\,)$ is the number of disjoint time periods for which r contains updated information for the node.

Let $\wp_i \subset \wp$ is the space of all possible resources that annotate the node v_i of $Tree\,(M, S)$, $i = 1, 2, \dots, n$. Further, if $r \in \wp_i \cap (W \cup E), Link(r)$ denotes the relevant reference to r. Let R is an arbitrary set of information resources, $Anot_i\,(R) = \wp_i \cap R$ and $Anot\,(R) = \{\,Anot_i\,\,(R) : i = 1, 2, \dots, n\}$.The actuality of $Anot_i\,(R)$ in node v_i of $Tree\,(M, S)$ is set with $T_i(R)\, = \{T(r, v_i\,) : r \in Anot_i(R)\}$, and of $Anot\,(R)$ – with $T(R) = \{\,T(Anot_i(R) : i = 1, 2, \dots,\, n\}$.

Due to the possible duplication of evidence resources in nodes in ASDQE realization it is better attach a reference ($Link$) to the relevant information resource in the node. This requires resources to be located in an appropriate repository (W, E or external for ASDQE), in advance, then instead of multiple $Anot$ to refer to multiple $Link(Anot) = \{\,Link(Anot_1),\, Link(Anot_2), \dots,\, Link(Anot_n)\}$. We shall maintain a list $List_i$, composed of couples <reference to resource r, actuality of r> to each node $v_i \in V$, which helps identify the attached relevant information sources to $v_i,\; i = 1, 2, \dots n$.

Definition 3. ***The conceptual model of methodology*** $\boldsymbol{M}$ ***for QE of*** $\boldsymbol{S}$ *is a tree data structure* $M_c =< Tree(M, S),\, V,\, Q,\, List >$ *composed of:*

- tree $Tree\,(M, S)$ that presents the system of areas/aspects of $S\,f$or QE in M;
- nodes $V = \{v_1, v_2, \dots, v_n\}$ of $Tree\,(M, S)$, corresponding to M indicators, as each of them is able to attach annotations of type P1. or P2., located in accessible repositories, including W and E;
- system of function and norms for quantitative or expert measurement $Q = \{Q_1(v_1, L_1\,), Q_2(v_2, L_2\,),\, \dots,\, Q_n(v_n, L_n\,)\}$ of the relevant aspects – quality criteria models;
- $List = ListRep \cup ListRes$ – union of two sets:
    - o $ListRep$ – list of couples $\{< Link(r)$, $T(r,\, v_0) >: r \in R\}$ to the node v_0 of the tree $Tree\,(M, S)$, in which r is an information resource that can be presented as a hypertext composed by texts $\{t_1(r), t_2(r), \dots, t_n(r)\}$, located in nodes $V = \{v_1, v_2, \dots, v_n\}$ of $Tree\,(M, S)$;
    - o $ListRes$ – list of couples $< Link(r)$, $T(r, v_i) >$ to each node $v_i \in V$, identifying information resources from $\wp_i$ that annotate $v_i,\; i = 1, 2,\; \dots, n$.

The essence of the idea in the model and the system for DQE is depending on the period for which the quality of the S need to be evaluated, $List$ dynamically to be changing. New information resources are included in $List$, not only if they are related to S and M, but if they are relevant to the auditing period; conversely, if the actuality of resources in the conceptual or computer model of S is expired, it will automatically be excluded from the $List$ of the current procedure for QE and/or it will be replaced by a new updated version.

The problem related to the automated creation of $Report$ is reduced to dynamic collection and/or creation of actual information resources, references to which then should be added to the nodes of the tree data structure. The information resources that are attached, thus to $Report$ are of type D1. or type D2. In all cases when an appropriate actual resource is available on W or E, the attachment is modelled by adding a pair <reference indicating the resource location, actuality of the resource to the measurement period> to the list of references in the corresponding node of the tree.

There are three approaches for creating information resources for indicators of M_c. **The first** („manual“) approach is linked to a specific moment of creation, whereby the actuality of the resource for nodes is also fixed. The latest information is required for formatting the second element in the $List$ pair. **The second option** involves the creation of a computational model S_e of S. In this case, on the basis of S_e are created procedures that can generate adequate information resources related to specific procedure for QE of S for τ periods. **The third option** to create an element of S_e lies in its full or partial realization in the computational model M_e of M. Such a solution has the disadvantage that as a consequence M_e model turns out to depend on the following development of S_e. Accepting the first and the second option as the basic working approaches for the creation of information resources, for designing of relevant ASDQE it is need to be proposed the computational model M_e of methodology M that is independent of any subsequent development of the information infrastructure E, and in particular of S_e.

Definition 4. The computational model of methodology *M* for QE of *S* is a tree data structure $M_e(\tau) =< Tree(M,S),\ V,\ Q_e, List_e, F_e >$, in which:

- $Tree\ (M,S)$ presents the criteria system (areas/ aspects) of S for QE on methodology M;
- $V = \{v_1, v_2, \dots, v_n\}$ are the nodes of $Tree\ (M,S)$, corresponding to indicators of M;
- $Q_e = \{Q_1^e(List_1, v_1, L_1),\ Q_2^e(List_2, v_2, L_2), \dots, Q_n^e(List_n, v_n, L_n)\}$ is a system of functions for measurement of the level of compliance of indicators on relevant norms in M;
- $List_e = \{List_1, List_2, \dots, List_n\}$ is a set of lists $List_i$ to each node $v_i \in V$ composed by pears $< Link(r),\ T(r, v_i) >$ that identify information resources r from $\wp_i$, annotating $v_i, i = 1, 2, \dots, n$;
- $F_e = \{f_1^e, f_2^e, \dots, f_n^e\}$ is a system of functions for measurement of the actuality of information resources for nodes $V, i.e. f_i^e\colon \wp \to T$, where $f_i^e(r) = T_i(r)$ for $\forall r \in \wp_i, i = 1, 2, \dots, n$.

The information resources can be created in the form of results by three types of reports in W and E_s:

C1. Reports that by a task involving parameter values that concern certain aspects, characteristics, elements, relationships and qualities of the subject S in E_s and through the use of **software tools from the information context** E_s, return informational resources to W that hold specified metadata;

C2. Reports of summarized results of surveys generated by the use of **standard software for survey analysis**.

C3. Reports – results by the work of a **special (copyright) software** from S_e^a and S_e^n, which on the basis of a time schedule of activities dynamically generate informational resources suitable for annotation of the nodes, making them available in W with the possibility of subsequent inclusion in M_e.

We will introduce further symbols and concepts for modelling and automated execution of assignments, including activities for creating resources $r \in \wp$, their deployment in E or W with attachment of relevant links to appropriate nodes of $Tree\ (M,S)$. Let $\tau \in T$ is a set of (relative) time periods within which standard the QE of S would be done. Normally, the standard periods τ for QE of S on a methodology are limited to one time interval.

Definition 5. We will say that f is the **function that accumulates information resources after a moment $t_0 \in \Omega$ for QE of *S* in the node v_i** of $Tree\ (M,S)$, if $f\colon [t_0, \infty) \to \wp_i$ and for $\forall t' \geq t_0, \exists\ \Delta = \{t_i^k : k = 1, 2, \dots, l_i; t' \leq t_i^1 < t_i^2 < \dots < t_i^{l_i}\}$, to which $A(f(t_i^\kappa),\ v_i) \cap (t' + \tau) \neq \emptyset$. $F_i(t_0)$ denotes the set of all functions accumulating information resources after a moment $t_0 \in \Omega$ for QE of S in the node v_i of $Tree\ (M,S)$.

Definition 6. We will say that f is the **function accumulating information resources after a moment $t_0 \in \Omega$ for QE** S in the node v_i of $Tree\ (M,S)$ for the period $\boldsymbol{\tau \in T}$, if $f\colon [t_0, \infty) \to \wp_i$ and of $\forall t' \geq t_0, \exists\ \Delta = \{t_i^k : k = 1, 2, \dots, l_i; t' \leq t_i^1 < t_i^2 < \dots < t_i^{l_i}\}$ to which $A(f(t_i^\kappa), v_i) \cap (t' + \tau) \neq \emptyset, k = 1, 2, \dots, l_i$ and $\cup_{k=1}^{l_i} A(f(t_i^\kappa),\ v_i) = t' + \tau$. $F_i(t_0, \tau)$ denotes the set of all functions accumulating information resources after a moment $t_0 \in \Omega$ for the period $\tau \in T$ for QE of S in the node v_i of $Tree\ (M,S)$.

Definition 7. We will say that f is the **function accumulating information resources** after a moment $t_0 \in \Omega$ **for QE of S in the node v_i** of $Tree\,(M,S)$ that includes period $\boldsymbol{\tau} \in \boldsymbol{T}$, if $f: [t_0, \infty) \to \wp_i$ and for $\forall\, t' \geq t_0, \exists\ \Delta = \{t_i^k : k = 1,2,\dots,l_i;\ t' \leq t_i^1 < t_i^2 < \dots < t_i^{l_i}\}$, to which $\mathrm{A}\,(f(t_i^{\kappa}), v_i) \cap t' + \tau \neq \emptyset,\ k = 1,2,\dots,l_i$ and $\cup_{k=1}^{l_i} \mathrm{A}\,(f(t_i^{\kappa}), v_i) \supseteq t' + \tau$.

For creation and maintenance of ASDQE, which can automatically generate information resources suitable for the attachment and actual for different time periods for QE of S in M methodology, systems accumulative functions suitable for the attachment to the nodes of $Tree(M,S)$ need to be modelled and designed. As above, let $\tau \in T$ is a set of (relative) time periods within QE of S shall be done.

Definition 8. The computational model of a process for accumulation of information resources for QE of $\boldsymbol{S}$ for time periods $\boldsymbol{\tau} \in \boldsymbol{T}$ by a time schedule Δ after moments $t^0 = \{t_i^0 \in \Omega: i = 1,2,\dots.n\}$ is the tree data structure $M_e(\tau,\Delta) = <Tree(M,S),\ V,\ Q_e,\ List_e,\ F_e,\ \mathcal{F}_e,\ \tau,\ \Delta>$, composed of:

- $Tree\,(M,S)$ – a tree data structure presenting the system from areas/ aspects of S for QE in M methodology;
- $V = \{v_1, v_2, \dots, v_n\}$ – nodes of $Tree\,(M,S)$, corresponding of M indicators;
- $List_e = \{List_1, List_2, \dots, List_n\}$ – a set of lists $List_i$ to each one node $v_i \in V$, composed of pairs $<Link(r),\ T(r,v_i)>$ that identify information resources from $\wp_i$, annotating v_i for which $\mathrm{A}\,(r,v_i) \cap \tau \neq \emptyset.\ i = 1,2,\dots,n,$;
- $Q_e = \{Q_1^e(List_1, v_1, L_1),\ Q_2^e(List_2, v_2, L_2)\dots,\ Q_n^e\,(List_n, v_n, L_n)\}$ – a system of functions for calculating the level of compliance of nodes to relevant norms in M;
- $F_e = \{f_1^e, f_2^e, \dots, f_n^e,\}$ – a system of functions for calculating the actuality of information resources for nodes V;
- $\mathcal{F}_e = \{F_1^e, F_2^e, \dots, F_n^e\}$ – lists of accumulating functions $F_i^e = \{f_i^k \in F_i(t_i^0): k = 1,2,\dots,l_i\}$ for the nodes of $Tree(M,S), i = 1,2,\dots,n$;
- $\Delta = \{\,T_i: i = 1,2,\dots,n\}, T_i = \{t_i^k : k = 1,2,\dots,l_i, 0 \leq t_i^1 < t_i^2 < \dots < t_i^{l_i}\},\ i = 1,2,\dots,n$ - set a time schedule to start the functions from $\mathcal{F}_e$.

On the basis of the computational model M_e, when initial time points to start activities for accumulation of information resources for v_i are given, they will be started by ASDQE in absolute time moments. At the beginning of the creation of models, $List$ contains only references to information sources that are not product of the current process for QE, but they are obsolete for it – regardless of the time period, which the next QE of S will be held.

In Fig.2. the assignment for automated collection of information resources for QE of S is indicated with $Task(\,\tau,\Delta)$. In addition τ-periods for which the QE procedure will apply and Δ - relative time points to start the functions for accumulation of information resource the assignment may contain additional information for the organization of the procedure for QE. In performing $Collate$ results $M_e(\tau',\Delta')$ are accumulated and $Task$ changes to $Task(\tau',\Delta')$.

The last stage ($Assess$) involves the selection of information resources by Rep and Res, accumulated in evaluation periods and creation of the final report-report $Report$, composed of two parts - a hypertext document (based on Rep) and a list of appendixes with information sources (located in W, E or external repositories identified by references to them). On $Assess$ stage on the basis of $M_e(\tau,\Delta)$ from the accumulated hypertext and the accumulated information resources $Report$ is formed.

3.3. General functional requirements to the ASDQE project

The analysis of the objects, models, procedures and workflows related to DQE (Fig. 2.) shows that the **ASDQE project has to include the following subsystems**:

A. *Conceptual modelling of methodologies* for dynamic (semi)evaluation of the quality of processes or their elements (sub processes, activities, subjects, objects);

B. Modelling of accumulation functions;

C. Computational modelling of methodologies within the information infrastructure E;

D. Accumulation of information resources and reports for dynamic (semi)-evaluation of the quality;

E. Organization and management of assignments and procedures for QE of processes and/or their elements;

F. Communication and collaboration between users and system.

Fig.3. presents the ASDQE architecture.

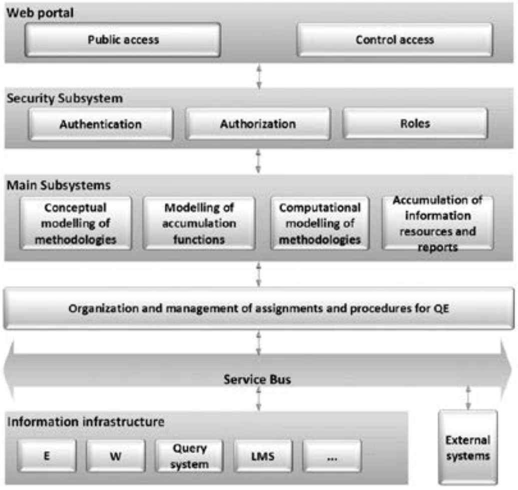

Figure. 3. Architecture of ASDQE

The main functional requirements to each one of the 6 sub-systems A – E are:

Subsystem A. (for conceptual modelling of methodologies for DQE):

- Modelling of methodology M_c for S type objects.

Subsystem B. (for accumulating function modelling):

- Design of accumulating functions and generating of information resources;
- Management of templates;
- Automated planning of time for templates starting and delivery of their results;
- Providing of REST and SOAP web services for access (from the level of other ASDQE subsystems) to the subsystem B functionalities.

Subsystem C. (for computational modelling of methodologies):

- Modelling and management of specific procedures for QE of different S_e objects and relevant computational models of methodologies M_e;
- Modelling of processes for accumulation of actual information resources;
- Adding of information resources from different types;
- Extracting of evaluation data for indicators on the basis of web services provided by external systems.

Subsystem D. (for accumulation of information resources and reports):

- Collecting of information resources related to QE of S on methodology M for a period of time;
- Export of information resources in different file formats.

Subsystem E. (for organization and management of assignments and procedures for QE):

- Processing of evaluative information on individual indicators;
- Providing information about the state of procedures in real time;
- Update of procedures;
- Continue (or not) of procedures;
- Report generation;
- Backup $Report$ in W for further use;
- Keeping of communication forms.

Subsystem E. (communication and collaboration):

- Internet access to the ASDQE functionality;
- System and Information Security.

3.4. ASDQE - Software prototype

The software prototype, named SyDQE (system for dynamically QE), is based on the architecture of Fig.3. and includes implementations of subsystems A. - E. The requirements to ASDEQ formulated in 3.3. set presented specifics of the prototype SyDQE as follows:

- to integrate multiple software solutions and a wide range of technologies - existing or developed for the purpose;
- to work within the various existing institutional infrastructure for a wide variety of platforms;
- to be a flexible open-access application.

SyDQE is implemented on the basis of the integration and development of these software solutions and technologies:

- *Web-based platform COMPASS* [19] for modelling of methodologies for QE and automation of NEAA procedures for assessment and accreditation in the field of HE – in the base of the development of A, B, D, E subsystems;
- *technologies and tools* of JasperSoft [20] - used for the development of all subsystems and a digital repository W of the prototype*;*
- *information systems and DB* of the infrastructure E of a particular institution (PU) as university systems for administration of students and teachers, LMS and others.

The digital repository of information resources W is created on the basis of the possibilities for organizing structured repositories of JasperSoft Server. Thus, W becomes a component of the university information infrastructure, and could be used by other university systems [21]. It is essential to note that in accordance with the selected software architecture model for integration [22], subsystems A., B., C., D. and E. of SyDQE are constructed on the basis of web services and integration with other elements of the institutional information infrastructure E. Within the study, experiments were performed in two integration approaches:

Approach 1. Using the prepared web services (based on *Jasper*);

Approach 2. Development of new web services (implemented through the submissions of the Moodle API web services).

The **subsystem A** (called A-Si) has been developed on the basis of the COMPASS system as the development of opportunities for its conceptual modelling of methodologies for QE. Firstly, a corresponding set of global formal parameters (e.g. time) is allowed to be defined to conceptual models of M_c methodologies. Their setting is strongly embedded in the prototype software realization. A-Si improves the COMPASS and with tools that allow conceptual models M_c of methodologies to give possibilities to separate methodology indicators to be attached templates for dynamic accumulation of information resources. These additional tools are developed using the *JasperReport Server* web services. Templates for generating of information resources are accessible from the *A-Si* in the stage of modelling of a procedure for self-evaluation and can be attached to indicators from the modelled criteria system.

The **subsystem B. prototype** (called B-Si) allows defining of accumulation functions (templates) using the capabilities of *JasperReport Server* and *JasperSoft Studio*, through their integration to ASDQE. The templates allow accumulation of data presented through tables and diagrams. What accumulation templates for information resources generation will be designed using *SyDQE* for a specific QE procedure depends on the existing IT institution infrastructure in which objects are functioning. The relevant formal parameters of each accumulating function which also depends on the specific procedure for QE and from the subject property should be clarified in advance. Some of these parameters (e.g. specialty, time) are global for all elements of the QE procedure. These parameters are derived from the model of methodology (*A-Si*). Local parameters are specific and only applicable to certain patterns of reference (e.g. courses in accreditation and QE of distance learning). Designed accumulation templates are compiled to a special internal format and stored in the W repository. Thus, they can be used both by the level of the system *JasperSoft* and the prototype (see D. subsystem) to accumulate relevant reports filled dynamically with data extracted from the corresponding data source.

The **prototype of subsystem C.** (called C-Si) is realized on the basis of COMPASS as a new functional extension of its capabilities for computational modelling of methodologies for QE. With its help, through an interactive interface, the methodology is computationally modelled and displayed as a tree data structure - a hierarchy of relevant components and simple indicators. On the basis of the tools developed in *A-Si* at some moment of the QE procedure on the methodology to relevant indicators could be attached unless concrete evidence and relevant templates of information resources created within the *B-SI* subsystem. The overall modelling of M_e methodology requires more sets of actual values of global parameters (incl. time) for the accumulation of information resources by the attached to its indicators accumulating functions (subsystem *B-S*i). Specific factual parameters are determined by the $Task$ assignment of the QE procedure. The parameters depend on the evaluated S object and the indicators related to them. In the prototype developed they and the local factual parameters are set by the user (see Subsystem D.). Furthermore, in order to carry out the QE procedure at this stage in the W repository, it is necessary to introduce an organization for storage of the dynamically generated information resources. A tree of folders is being created via *JasperReport Server* web services as using names consistence: the name of the root of the tree matches to the procedure name and folder names – identifiers of report templates created within *C-Si*. These folders will store evidence generated through the subsystem D functionalities.

The prototype of subsystem D (called *D-Si*) provides modelling and implementation of the specific QE procedure on a specific methodology. This practically means to cause the performance of the accumulating functions (modelled by *B-Si*) to the attached indicators of M_e (via *C-Si*) after setting the actual values of their local parameters. The implementation is on the basis of the *Jasper* tools integration. For *D-Si* users for each accumulating template are being extracted automatically the names of local templates parameters and the corresponding generated a list of possible values from which users can choose - for what values of the parameters to be accumulated information resources. Actual values of global parameters are set accordingly. The accumulated information resources are being stored in the W repository according to the organization.

The **prototype of subsystem E.** (called *E-Si*) is developed in the form of a new functional extension of *COMPASS* by the integrated *Jasper* tools. *E-Si* allows for a specific QE procedure and computation model of methodology M_e to be attached appropriate information resources accumulated to a certain time. The extension retrieves all information resources accumulated for the procedure at the time that are stored in folders of the W repository, using the web services of *JasperReport Server*. The extracted files can be added in a specially intended for this purpose folder of *SyDQE*. As a next step, the accumulated materials located in this folder can be attached to the selected indicators of the methodology as new evidence materials. *E-SI* uses functionality inherited from *COMPASS* for generating of the $Report$ in the form of reports for (self-)evaluation with references to information resources located in W.

The fact that *COMPASS* is web-based allows on its base to be simulated and **subsystem F** (called *F-Si*). Currently it uses to a full degree the functionality inherited from *COMPASS*. Its improving will be done within the next development of the prototype.

3.5. Methodology for creating of models and systems for DQE

To implement the DQE applications of specific classes of objects with the software prototype *SyDQE*, the methodology for preparation should be presented, as well as planning and implementation of such experiments. On the basis of the foregoing considerations proposed is a general methodology for creating of models and systems for DQE of specific object S in a given subject area. The **methodology for creating applications for DQE objects S** includes three main stages.

Stage 1. Creation of the methodology M for S QE, incl.:

1. ($Start$) Start of *preparatory activities* – analysis of the state of studies and good practise within the QE of object by S type; review and systematization of the available software sources, etc.;
2. ($Digitize$) *Studying and digitizing in* W of the information context of S within the next activities will be held;
3. ($Design$) *Creating* (incl. adaptation, replication and/or new designing) **of the methodology** M for S *QE*;
4. ($Assemble$) *Studying the information context* E_s of S and its components, especially on

the basis of information systems located in the information infrastructure E of the institution;

5. ($ReDesign$) Defining rules for conduction of subsequent updates of M, incl. on the baisis of results $Report$ form previous procedures for QE of S;

Stage 2. Creation of conceptual and computational models:

6. ($c - Model$) Designing and creating conceptual models (M_c, S_c);

7. ($e - Model$) Designing and creating computational models (M_e, S_e).

Stage 3. Modelling and application of the QE procedure:

8. Model of procedure for applying the methodology M for QE of S object.

9. Application of the QE procedure.

Within Stage 2 and Stage 3 of the methodology it is recommended for the proposed architecture of ASDQE to be followed.

The created models, methods and tools are fairly universal. Thus, they can be used for modelling and automatization of the processes for DQE in different subject areas.

4. Results

The methodology and the software prototype developed on the basis of the general theoretical model are probated for different objects (courses, programs, e-courses, etc.) and processes for DQE in HE with vary complexity.

4.1. Conceptual and Computational Modelling of NEAA Procedures

In conformity with the Bulgarian Higher Education Law (art. 11), each university is subject to periodic external evaluation and accreditation by the NEAA (http://www.neaa.government.bg/) on relevant criteria and regulatory procedures. NEAA criteria systems are hierarchical. The composite indicators are organized in three levels, called standards, criteria and criteria contents (indicators) in the new NEAA criteria systems adopted in 2016 and respectively – criteria, characteristics and indicators in the former NEAA criteria systems. Measures (weight coefficients approved by the NEAA Accreditation Council) of the conformity of the evaluating objects' characteristics to the criteria content use expert evaluation whereby the evaluation of each composite indicator is obtained as the sum of the evaluations of the criteria content of a lower level.

Three applications for DQE in program accreditation of universities are developed, respectively in the case of DL (4.1.), professional field (PF, 4.2.) and doctoral programmes (4.3).

The applications are developed on the basis of the methodology for creating models and systems for DQE (see. 3.5.). **Stage 1** of the methodology includes five sub-stages for carrying out preparatory activities that are essential to creating relevant conceptual models M_c. Although for each of these applications exists legally adopted criteria system for QE on relevant objects (DL, PF, doctoral programmes) at this stage of the methodology it is crucial to analyse:

- Relevant criteria system M – in order to be seen for which components of the evaluated objects S – elements, states, results refer individual criteria and also to be identified (sub-stage $Design$) norms for their quantitative or expert measurement;
- possibilities for automated data retrieving to evaluate the criteria of the NEAA criteria system - in order to determine the information resources suitable for justification of evaluations.

The analysis purposes to create suitable supporting documents to be attached to tree nodes v_i related to criteria or indicator K_i of M_c ($i = 1, 2, \ldots, n$). The analysis involves a detailed introduction to the elements of the information infrastructure of the institution E (functionalities, way of realization, DB structure and tables that store data for S, access, etc.). Analyses were performed after studying the data context (sub-stage $Digitize$) of the evaluated objects S. The results are presented in the form of tables. For each criteria the content of different levels of M, in accordance with their original numbering of the NEAA criteria system are described for which component of the evaluated object concerns, norm for measurement, and supporting documents related to them, which can be accumulated by the university information systems to assist in the formation of the evaluation of the quality indicator. Supporting documents are in different forms – reports, analysis, surveys, etc.

The software prototype SyDQE (see 3.4.) is used in **Stage 2** of the methodology for creating applications for DQE. With its subsystems on the basis of the results of Stage 1 are created relevant conceptual and computational models of methodologies for QE (M_c,M_e), then experiments in relevancy with Stage 3 are carried out. The implementation of Stage 2 observes the same pattern (defined by SyDQE) for the three applications. To illustrate the methodology, only the methodology of the application for QE of DL is presented, where it focuses on specific moments depending on the evaluated object, namely the establishment of accumulating templates to generate information resources. The logic in the implementation of Stage 3 follows directly by the functionality of the sub-system D-Si of SyDQE and therefore it is not discussed here.

In conformity with the regulations, DL in Bulgaria can be organised only by universities that have received program accreditation under the relevant PF. For accreditation of DL (according to the NEAA former criteria system for evaluating DL [22]), it is necessary to meet the requirements of 4 criteria that apply only to educational activities specific to DL. For the fourth criteria, 46 indicators are defined divided into 12 quality characteristics.

The analysis is made in terms of the relevant characteristics and indicators of DL quality, relative to each of the fourth criteria of the criteria system. Table 1. presents the part of analysis of **Characteristics 1.1.1.** *Educational documentation for the specialty conducted in distance learning* of **Criteria 1.1. Educational goals and documentation**.

Table 1. Analysis of Characteristic 1.1.1. of Criteria 1.1. (DL)

Indicator at different level/*Norms* Supporting documents	Max
1.1. Educational goals and documentation	3
1.1.1. Educational documentation	2
1.1.1.1. Curricula *Equality, use standards for educational documentation, contain package with materials for student, qualification characteristics, methodologies, resources and facilities for students with special educational needs*	0.3
Formally adopted by the university methodological standards for educational documentation, qualification characterristics, curricula Lists of compulsory, optional and faculty subjects Ratios (including compulsory, optional and faculty subjects) in number and credits Ratios of the number of credits for regularly and distance learning for the specialty Curricula - number of credits List of separate positions and formulated functional duties of administration whose implementation ensures the required level of the documentation	
1.1.1.2. Educational goals *Clearly defined in the educational documentation*	0.3
Data for specialty annotation and students' GPA Analyses of the surveys for course quality evaluation by experts	

The analysis showed that automated data retrieving by the university information infrastructure to support the evaluation process are possible for **87% of the indicators** (40 of 46) of the criteria system for DL evaluation on the basis of 64 accumulated resources.

To build the application for DQE in DL accreditation by the NEAA criteria system is used the software prototype SyDQE (see 3.4.). Thanks to the tools for automation of the procedures for objects QE set out in the system, the performance of the majority of the methodology sub-stages by means of its subsystems is relatively easy.

A special case is using the Subsystem B (B-Si) capabilities to define accumulative functions (templates), depending on the specific procedure for QE and IT infrastructure of the institution. Clearly, the automated QE of DL requires collection, analysis and interpretation of a huge amount of data in terms of the attitude of students and experts to learning courses, software tools used, etc., from different information systems [23]. Therefore, the choice of templates appropriate for QE of DL is made on the basis of the analysis results. At this stage of development of the application experiments are carried out for the application of two integration approaches mentioned in 3.4 – by using web services of Jasper and by developing specific web services. Some of the templates for generation of information resources suitable for QE of DL are developed on the basis of these approaches. In addition to generating and collecting documents of the type "*Analysis of completed questionnaires*" by the developed template a package [24] is created from questionnaires for QE of e-course by experts and students. Tools for conducting online surveys and use of the results for the needs of the template are developed.

4.2. Conceptual and Computational Modelling of e-Courses

The section presents example of the creation of methodologies and tools for DQE of e-courses.

The development of application follows an action plan according to the methodology from 3.5. The implementation of **Stage 1** requires the methodologies for object QE to be created previously (sub-stage $Design$). In studying the information context (sub-stage $Assemble$) is given a typical Bulgarian HEI. The implementation of **Stage 2** is simplified because developed systems for DQE is selected specific private case of target object and evaluation aspects. This eliminates the need to create relevant conceptual models and reduce the complexity of the developed computational models. In the examples, the computational models are set firmly in the software implementation. For creation of software models of appropriate accumulative functions is used an approach similar to the descriptions in the software prototype *B-SI* of ASDQE. The implementation of **Stage 3** is also simplified and its sub-stages are set firmly in the software implementation. The realization of applications is consistent with the proposed ASDQE architecture and uses integration and technological solutions applied to the ASDQE prototype.

The application for DQE of e-course aims to evaluate e-courses in "distance learning" aspect - the **quality of e-course conducted in distance learning** to its characteristics as students' activity, success, etc.

When starting the preparatory activities (sub-stage $\boldsymbol{Start}$) an analysis of the research state, practice in the field of evaluation and review of the available information and software sources is made. The analysis justifies the rationality of creating application for QE of S object (e-course in DL aspect). As a result of the analysis are determined the characteristics of the developed application for QE of S object taken into account when implementing the various stages of the methodology.

The survey of the informational context of S and its digitization in W(sub-$stage$ $\boldsymbol{Digitize}$**)** involves analysing the legal documents N of NEAA. Related indicators are researched in details: control of the training schedule; activity of students and teachers; success of students; learning resources and activities. In a result hierarchical methodology (Table 2.) is proposed that includes the quality characteristics of two levels (criteria and indicators).

Table 2. A model of the methodology for QE of e-course („distance learning“)

Criteria	Indicator
Activity in communication tools	Activity in tools for asynchronous communication
	Activity in tools for synchronous communication
Control of training schedule	Control of training schedule (teachers)
	Control of training schedule (students)
Workload of students and teachers	Workload in learning activities and resources (students)
	Workload in learning activities and resources (teachers)
Success of students	Success in activities for collaborative assessment (by students) of assignments
	Success in activities for adding and organizing terms and definitions
	Success in activities for interactive presentation of the learning content
	Success in activities for collaborative development of web pages
	Success in activities from external sources
	Success in assignments
	Success in tests
Learning activities and resources	A variety of learning activities and resources

The quality evaluation of the object S on methodology M requires studying of its informative context (sub-stage $\boldsymbol{Assemble}$). This requires familiarization with the elements of the computational model of S, i.e. studying *Moodle* (functionalities, DB structure and tables, access, etc.). As a result, the study identified the data stored in the respective tables of the *Moodle* database (total 75) - for different types of learning activities and resources that can be used for accumulation of supporting documents in **Stage 2**.

The computational model of S does not need to be developed in **Stage 2**. It is supported in the database. Created is only the computational for QE methodology. The realization is by *Jasper* tools and is a hierarchy of folders in *JasperReport Server* repository, corresponding to indicators of the methodology. There is a possibility (again through *Jasper*) to indicators in the tree to be attached corresponding templates of information resources (through compliance of folder names with these of the templates).

The choice of templates appropriate to QE of e-course is made on the basis of results of the analysis and subsequent systematization which of the data in the *Moodle* DB for learning activities and resources in e-course conducted can be accumulated automatically for each of the M criteria. As a result (through *JasperSoft Studio* design tool), 8 accumulative templates are developed. Recourses generated by templates are stored in the corresponding folders (model of M indicators).

The modelling of a process for the methodology applying in QE of a specific object S requires setting values of local and global parameters of accumulative templates of reports attached to criteria and indicators which are needed for the dynamic creation of supporting documents. For all attached criteria and indicators of the object accumulative templates are set to generate supporting documents after starting the methodology on a specified date (end of the year).

The evaluation assignment ($Task$) includes a schedule for starting accumulative functions for generation of supporting documents and their attachment to the criteria and indicators of the object at the end of each school year, stating the time period T of the S life cycle, on which QE will be made – start and finish date of the evaluation period.

The results of the **QE procedure** ($Collate$), related to S received by the $Task$ assignment on the basis of M methodology are in the form of a set of supporting documents (Res) in the form of reports directly related to the quality of different characteristics of the e-course. Dynamically generated supporting documents (Res) are stored in the *JasperReport Server* repository on specified dates and can be attached as supporting documents to the QE procedure.

5. Conclusions

The study examined the general theory, existing organizations, models, standards and systems for quality evaluation in higher education. On the basis of the theoretical study, a number of conceptual and computational models are proposed. In consequence, the architecture of a software system for dynamic quality evaluation is defined and a corresponding software prototype is built over an existing university information infrastructure. General models are applied for dynamic quality evaluation of different objects in the field of HE. The developed methodologies and software tools **are tested in real situations at the University of Plovdiv** for dynamic quality evaluation of objects and prove the adequacy of the models.

Due to their community, the results obtained in the study could be r**eplicated for QE of objects in other subject areas.** The results could be on the basis of research in the following areas:

- improvement of models for DQE of the examined objects by adding new accumulating functions;
- replication of the results for other universities;
- development of applications for DQE of other objects within the universities.

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