An Ontology-Driven Rule Enforcement Framework for Governing the Student Evaluation Lifecycle in Sri Lankan Higher Education

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Abstract

The aspects of governance, regulation, and transparency are essential parts of modern educational service management systems and, especially, of the Student Evaluation Lifecycle (SEL). On the other hand, student evaluation processes in higher education institutions operate with inconsistent policies, humanly understood regulations, inefficient control procedures, and informal enforcement of rules, which can result in inconsistencies, lack of transparency, and non-compliance with the SEL process. There is no study that would explore the problem of integration of governance requirements, ontology-based rule representation, and rule enforcement processes for student evaluation. The ontology of rules and rule-enforcement sub-framework (RORESF) proposed in this study includes institutional governance rules and rule-enforcement of regulations related to SEL. What makes the ontology of rules special is the combination of rule ontology, governance rules, and multilevel business rule enforcement in a reusable framework tailored to evaluate higher education processes. The ontology is developed following a classification of business rules and the use of an action enablement rule paradigm together with various forms of enforcement mechanisms. Business Process Model and Notation (BPMN) is employed to model the rule ontology, governed processes, actors, decision points, and enforcement mechanisms to ensure that the process becomes transparent. A hybrid approach that includes design science research methodology (DSRM) and interpretative phenomenological analysis (IPA) was applied in this research. The results show that ontology systematically identifies and represents governance rules and links institutional regulations with evaluation procedures with the help of transparent BPMN models. Experts evaluated the ontology and found it to be correct, complete, consistent, and comprehensible.

Keywords: Business Rules, Educational Service Management, Governance and Compliance, Student Evaluation Lifecycle (SEL), Rule Ontology, Rule Enforcement

INTRODUCTION

This research addresses the development of an effective Educational Service Management Framework that will enable the achievement of governance policies as well as enforcement of rules in the SEL. Existing studies also lack a formal ontology that represents service rules and stakeholder responsibilities within higher education student evaluation processes. Consequently, universities continue to experience governance, compliance, and coordination challenges, particularly in complex evaluation environments involving multiple stakeholders.

Therefore, persisting inconsistencies in the current SEL continue to create serious difficulties in establishing uniform and fair procedures for final evaluation at the higher education institute. Besides, the lack of adequate monitoring functions and an institutional operating mechanism in the existing SEL limits efforts towards pursuing standardization in the higher education sector. In view of these limitations, this research proposes the development of a rule ontology and a rule enforcement sub-framework for responsible coordination in SEL. Accordingly, the research objective is to design, develop, and validate an educational service management framework by developing a service rule ontology and a rule enforcement sub-framework for the SEL, thereby improving governance, compliance, and stakeholder responsibility coordination.

The research objective of developing a service RORESF for SEL has been achieved. The proposed rules are significant to both designers and developers of intelligent IT-Based systems in the effective management of student evaluation.

The business rule classification guideline recommends a conceptual framework that categorizes business rules for

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analysis purposes (Eclipse Process Framework. (n.d.). Business Rule Classification (Guideline). There are three major categories, namely structural business rules that define domain terminology and fact-based relationships essential for representing business knowledge, decision logic, which represents a business-rule subset that drives business results by utilizing normative, guiding, enabling, acting, computing, and inferential business rules, and process flow business rules that manage activity execution flow in workflows independently of business decisions' logical reasoning. Finally, business decisions' logical reasoning is categorized under subcategories, namely mandatory constraints that prevent invalid business transactions, business guidelines that indicate undesirables without halting business process execution, Action Enablers that launch further business process execution, Computation business rules that apply computational formulas for calculating new values, and Inferential business rules that produce new facts for business reasoning engines (Eclipse Process Framework. (n.d.). Business Rule Classification (Guideline).

While this classification provides a generic foundation for business rule analysis, it does not explain how these rules can be systematically applied to higher education governance or to SEL. Moreover, existing studies do not identify which business rule categories are most appropriate for coordinating stakeholder responsibilities during student evaluation. Classification of business rules could also cover the following: Action Enablers, Guidelines, Mandatories, Computation, Inferences. Among all the above-mentioned types of business rules, the action enablers type is chosen for use in this research because of its direct contribution to the coordination of the sequence of responsibilities and automatic performance of the activities related to student evaluation. It is one of the distinctive features of the proposed methodology.

The notion of enforcement level captures the degree to which a business rule will be enforced in an organization's operational and information systems, and presents a scale that spans from highly enforced business rules, where violation is disallowed and results in definite prevention or penalty, to rules that are potentially overridable by authorized parties following violation, and finally to guideline business rules that are assessed and perhaps noted but do not prevent execution in case of violation. This also allows a separation between the meaning and implementation mandate of a business rule, such that diverse governance strategies not accompanied by this higher-level framework would fail to meet complex organizational requirements from a control vs flexibility perspective and thus provide guidance in relation to whether rules are encoded in executable logic versus merely tracked in guidance logic in an implementation context (Hinkelmann, n.d.). This serves to provide a better understanding with regard to the expected system behavior and the organizational processes related to rules, hence promoting the management, compliance, and flexibility of business rules in a complex business environment (Business Rules Group, 2010).

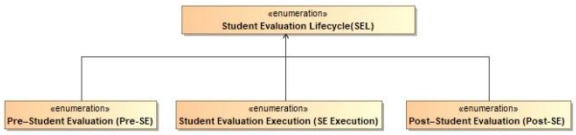
Therefore, compared with existing governance and business rule enforcement approaches, the proposed framework integrates three complementary components: (i) a Service Rule Ontology for formal knowledge representation, (ii) an Action Enabler-based Rule Enforcement Sub-framework for responsibility coordination, and (iii) governance policy enforcement across all phases of the SEL. This integrated approach addresses an important research gap that has not been sufficiently explored in previous studies, particularly within the Sri Lankan higher education context.

Student Evaluation Lifecycle (SEL):

SELs are predominantly used by universities and are known to be very complicated, in that they involve many stakeholders, have interactive relationships between them, and take up a lot of time. Also, in SELs, the assessment process is divided into different stages, and all of them are undertaken for a considerable amount of time. Consequently, it is very hard for the stakeholders to get a holistic view of the entire process. It is a problem in developing ITBS. Due to the complexity of SEL, the problem becomes even more important because the existing information system supports these tasks on an individual basis without having a framework that helps to follow policies during the whole evaluation process. The problem is particularly important within the framework of Sri Lankan universities, where student evaluations should be performed under university rules and multiple parties are involved.

This SEL is divided into three major phases, as depicted in Figure 1, namely Pre-Student Evaluation (Pre-SE), Student Evaluation Execution (SE Execution), and Post-Student Evaluation (Post-SE) phases.

Figure 1: Student Evaluation Lifecycle



Source: Developed by Researchers, 2026

Pre–Student Evaluation (Pre-SE) Phase:

The student evaluation process starts at the Pre-SE Phase of the SEL. This is the first phase of the student evaluation process and involves many important activities, including the development of evaluation criteria, securing all approvals, and the issuance of appointments, which are all important in the initiation of the student evaluation process.

Student Evaluation Execution Phase (SE-Execution):

After the successful completion of the activities in the pre-SE phase, the process continues to the Student Evaluation Execution (SE-Execution) phase. The concern of this phase is the student evaluation process during the period of examination, particularly the execution of the student evaluation activities strictly in accordance with the policies and guidelines of the institution.

Post–Student Evaluation (Post-SE) Phase:

After the process of examination is complete, the Post-Student Evaluation Process starts. This process entails a wide range of post-examination processes such as the evaluation and marking of the examination scripts, preparation of mark sheets, awarding of grades, recording of results, and communicating results of the evaluation process. Moreover, this

process offers a framework whereby students are able to access their results as well as express their inquiries, concerns, and/or appeals regarding their results of the evaluation process. The proposed Educational Service Management Framework supports governance and rule enforcement across all three SEL phases by ensuring that stakeholder responsibilities are coordinated through formal service rules, institutional policies are consistently enforced, and compliance can be systematically monitored throughout the complete SEL.

LITERATURE REVIEW

Moreover, the application of the aforementioned concept has been found to be effective in the management of complex knowledge structures in the context of educational systems, particularly in managing complex situations involving a number of stakeholders and complex interconnected processes. As may be understood from the aforementioned literature, the application of the concept of ontology-based models has been found to be effective in providing a sense of clarity, as well as ensuring the development of interoperability in the context of educational technologies (Chimalakonda & Nori, 2020). According to this concept, the application of rule ontologies has been suggested as a means of providing a platform for the implementation of governance policies and institutional rules. In the context of higher educational institutions, the application of the aforementioned concept may be used for the development of evaluation policies, approval, and compliance constraints. Hence, the application of the aforementioned concept may be identified as an effective means for the development of traceable student evaluation management systems, particularly in the context of centralized educational institutions.

The difference also lies in the level of enforcement, which can be compulsory, guidelines, and others (Hinkelmann, n.d.). This is important since the level of enforcement of the rules provides a structured way of differentiating between institutional rules that are inflexible and institutional rules that are flexible. With regard to higher education institutions, the inclusion of the level of enforcement of the rules in student evaluation management systems is imperative since it ensures that key constraints are encoded. Moreover, enforcing the rules ensures that the evaluation of the institution is done, and this is vital for public universities.

It is evident from the above that the precise specification of formal business rules is an essential factor that ensures consistency and traceability within information systems. As Feuto Njonko et al. (2014) indicate in their study, the use of controlled natural languages with the ability to fill the gap between business logic and formal logic is essential. It is evident from the study that there is a need for precise rules that are understandable. This is an essential part of higher education institutions, where there is a need for specifying policy with regard to system rules. This study has reiterated the need for precise specification of formal business rules with regard to the development of management systems that evaluate students.

In this regard, a detailed discussion regarding the Semantic Web Rule Language (SWRL) and its expressive extensions, particularly regarding the integration of ontologies and rule-based reasoning systems in the Semantic Web, has been provided in research by Lawan and Rakib (2019). The SWRL extends the Web Ontology Language (OWL) through the integration of conditional logic, thereby increasing the expressiveness and computability of the system. All these components might become very useful in the development of knowledge-based systems since it becomes necessary to develop consistent, compatible, and computable rules to develop knowledge-based systems. The SWRL can become very useful in the development of governance systems since it will help to develop semantically accurate and computable rules. Integration of the SWRL with ontologies relating to the field of education will be very useful in developing the student evaluation management system.

The importance of governance aspects in educational information systems is further emphasized in the research conducted by Turnbull, Chugh, and Luck (2022), as it offers a comprehensive analysis of different aspects of various policy factors that affect learning management systems in higher educational institutions. The research has emphasized different aspects of governance, such as access management, content quality, data privacy, integrity of assessments, and maintenance of systems, while highlighting the importance of learning management system policies, which extend beyond technical aspects, playing an essential role in governance, promoting transparency, accountability, and consistency in operations. The research is significant in environments where operational challenges are critical, and it offers significant guidelines on developing governance-based rule enforcement and ontology for student evaluation management systems, especially in Sri Lanka.

The classification of business rules also facilitates the analysis and management of rule-based information systems. Business rules can be classified as structural, decision logic, and process flow business rules, as defined by the Eclipse Process Framework (EPF). The classification of business rules facilitates the separation of the logic of decision-making and the flow of the process (Eclipse Process Framework [EPF], n.d.). The differentiation of business rules, as applicable to the student evaluation management systems, can be used for modeling roles and responsibilities of academics. The differentiation of business rules is also relevant with respect to the development of rule ontologies based on the policies of the governing bodies of higher education institutions.

The lack of visibility in the process has been identified as one of the most significant issues in dealing with the processes associated with evaluation. The need to apply rule-based process models in ensuring process compliance and transparency was highlighted in previous studies (Business Rules Group, 2010). The inclusion of rules in the process of executing workflows makes it easy to monitor the progress of activities and ensures accountability on the part of different stakeholders. This is especially important in dealing with the complexity of student evaluation management processes.

Lastly, ISO 21001 is a standard for a management system that is applicable in educational organizations, with a focus on governance, consistency of processes, as well as satisfaction of stakeholders. By incorporating the ISO 21001 principles, it is possible to have governance requirements integrated into the student evaluation management systems' rule enforcement mechanisms. All the literature reviewed highlights the significance of the rule enforcement mechanisms within educational information systems.

Though research on rule-based approaches and ontology-driven approaches is available, research on the application of rule ontologies and rule enforcement frameworks for student evaluation is lacking in Sri Lanka. This is a research gap, and it is an opportunity to use rule-based approaches for modeling the actors, activities, and processes involved in student evaluation, and for organizing the activities using rule-based approaches.

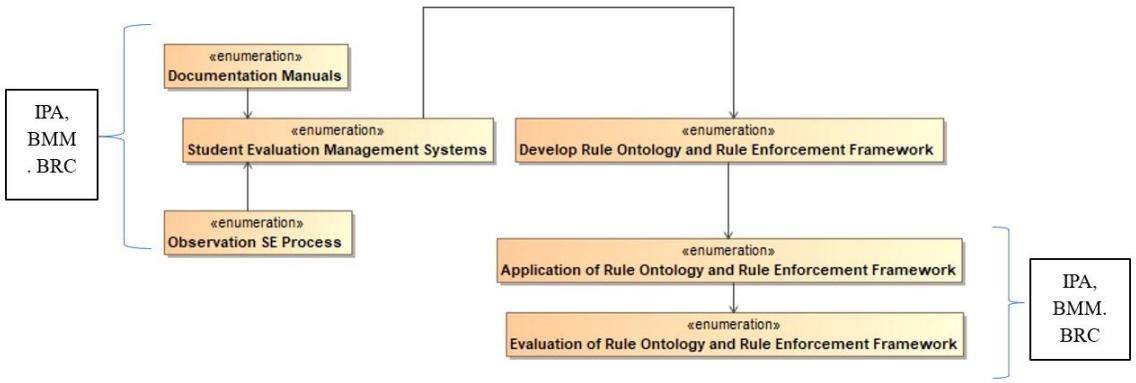
However, no studies have identified an ontology-driven rule enforcement framework in the Sri Lankan context that investigates the SEL. Therefore, a clear research gap exists in this area. By applying a rule-based ontology, the processes and activities associated with the SEL can be systematically identified and analyzed to evaluate responsibility coordination among relevant stakeholders.

MATERIALS AND METHODS

This study employs a mixed-methods research paradigm as depicted in Figure 2 below, which consists of two related methodological approaches: the Design Science Research Methodology (DSRM) and the Interpretative Phenomenological Analysis (IPA). These two methodological approaches were deemed suitable for this research since the research required the design and development of technological artifacts as well as comprehension of the stakeholders' experiences and governance issues in SEL. The focus of design science is on the application of knowledge to create new artifacts that address identified human and organizational needs. Accordingly, DSRM guided the identification of the research problem, the specification of design objectives, and the design, development, demonstration, and evaluation of the proposed Rule Ontology and Rule Enforcement Framework.

This is unlike IPA, which is a qualitative research methodology that is interested in exploring how people make sense of their experiences (Smith et al., 2009). The focus of IPA is based on the theoretical foundations of phenomenology, hermeneutics, and idiography, which try to interpret meanings based on the viewpoints of the participants in particular settings. In this study, IPA was used to examine how university stakeholders understood and experienced governance policies, institutional responsibilities, business rules, and rule-enforcement practices associated with student evaluation management. The findings generated through IPA provided the contextual and experiential knowledge required to define the concepts, relationships, responsibilities, constraints, and rules incorporated into the artefacts developed through DSRM. Therefore, IPA supported the empirical investigation of the problem domain, while DSRM provided the structured process for transforming the findings into practical and evaluable research artefacts.

Figure 2: Hybrid Methodology Process for Pre-Student Evaluation



Source: Developed by Researchers, 2026

Moreover, this research follows the Business Motivation Model (BMM) developed by the Business Rules Group (2010) and the Business Rule Classification (BRC) guideline developed by Olea (n.d.) as its underlying standards.

The integration of DSRM and IPA enabled an iterative relationship between qualitative inquiry and artefact development. The experiences and interpretations obtained from institutional stakeholders were analyzed to identify governance requirements and rule-enforcement problems. These findings informed the development of the rule ontology and rule enforcement framework, while feedback obtained during expert validation was used to refine the proposed artefacts. Hence, methodological integration allowed for the development of artifacts that were theoretically found, contextually meaningful, and consistent with the operational and governance needs of the student evaluation environment at the university level. Data collection was guided by IPA methodology and used semi-structured interviews of 30 carefully chosen domain experts at Sabaragamuwa University of Sri Lanka. These experts comprise the Examination Registrar, Dean, Head of Department, Subject Coordinators, Academic members, Subject Management Assistant, and other officers responsible for student evaluation governance and administration. The participants were selected in accordance with their professional duties, practical experience, decision-making rights, and direct involvement in the development of student evaluation policies and procedures.

Each participant was contacted formally and provided with information regarding the purpose of the study and the interview process. Informed consent was obtained before the interviews were conducted. A semi-structured interview guide containing open-ended questions was used to examine participants' experiences and perceptions concerning

governance policies, stakeholder responsibilities, existing business rules, institutional constraints, coordination practices, and rule-enforcement challenges within the SEL. Follow-up and probing questions were used when clarification or further explanation was required. The interviews were conducted individually face-to-face, lasted approximately 10 minutes, and were audio-recorded with permission for subsequent analysis. The interview data were then examined using IPA procedures to identify significant statements, experiential themes, recurring governance issues, and domain concepts relevant to the development of the proposed artefacts. The process of developing ontology follows guidelines of ontology engineering in terms of extracting concepts of the problem domain from relevant institutional documents and interview data, designing classes and relationships between them, specifying constraints in terms of responsibility-based rules, and validating with subject-matter experts. The ontology rule enforcement framework was developed based on expert feedback to ensure their conceptual accuracy, practical relevance, consistency, and suitability for supporting governance-based SEL.

RESULTS AND DISCUSSION

Rule Ontology and Rule Enforcement Sub-framework for pre- SE

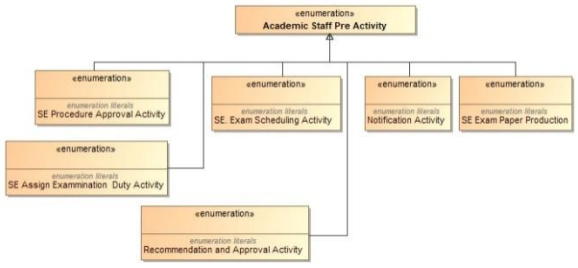
Within the Pre-SE Phases, it is essential to ensure that all prerequisite activities such as recommendations, approvals, and registration procedures are fully completed. These preparatory activities involve multiple actors within the academic domain and are critical to the effective scheduling and organization of the evaluation process. The pre-SE process can be broadly categorized into three primary groups:

1. Academic staff pre-SE activities
2. Non-academic staff pre-SE activities
3. Candidate for pre-SE activities

Academic staff pre-SE activities

During the pre-activity phase in the SE for academic staff, there are six different sub-processes as follows (see Figure 3): SE Procedure Approval, SE Assign Examination Duty, SE Exam Scheduling Activity, Recommendation & Approval, Notification, and SE Exam Paper Production.

Figure 3: SE Academic Staff Pre-Activity ontology



Source: Developed by Researchers, 2026

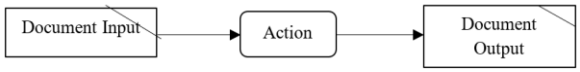
There are two significant sub-processes in the Student Evaluation Procedure Approval process: the Faculty Board Recommendation process and the Senate Approval process. These two sub-processes are responsible for the recommendations and approval of vital academic positions like the Paper Setter, Paper Moderator, First Marker, and Second Marker. As such, this section is devoted to the development of Rule Ontology and rule enforcement on academic positions but restricted to the Pre-Student Evaluation stage.

The Pre-Student Evaluation stage is characterized by certain rules regarding individual activities that provide a smooth progression from one stage to another in the evaluation process. In the case of this research, rules and rule enforcement will be developed for the "Student Evaluation Procedure Approval" process, particularly the pre-SE stage.

Rule Enforcement for Paper Setter

Input-Action-Output approach is followed by business rules to provide consistency and clarity in decision-making processes. Input of a document means the information, facts, or events that are fed into the business system. Forms, requests, or transactions are examples of document inputs. The action is associated with the set of business rules and decision logic, where decision logic evaluates inputs and imposes constraints to determine validity, calculation, or output. The output from such a process is the Document Output, which comprises approvals, rejections, notifications, recommendations, or records generated by the rule. Figure 4 below depicts the classification of business rules.

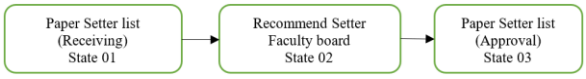
Figure 4: Action enablers business Rule classification



Source: Developed by Researchers, 2026

The Paper Setter is recommended by the Faculty Board, and the details are as follows: [Figure 5]

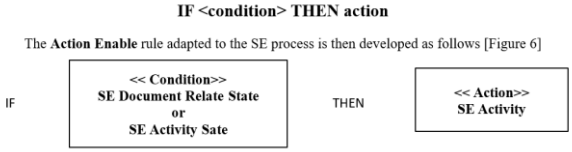
Figure 1: Faculty Board recommended state



Source: Developed by Researchers, 2026

To establish the rule governing the recommendation of the paper setter by the Faculty Board, the "Action Enable Rule" under the Business Rule Classification (Guideline) is adopted. The common format of the action enable rule is defined as follows:

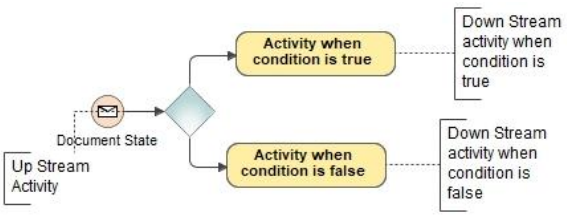
Figure 2: SE Action Enable rule



Source: Developed by Researchers, 2026

The document-based Student Evaluation (SE) rule adopted in this research is conceptualized and articulated through a Business Process Model and Notation (BPMN) diagram, as shown below [Figure 7].

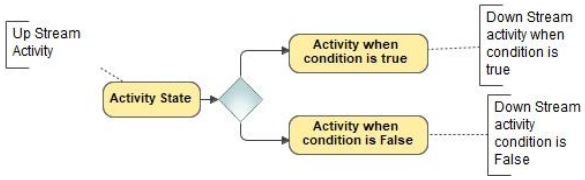
Figure 7: Document-based SE Rule



Source: Developed by Researchers, 2026

The Action-based Student Evaluation (SE) rule adopted in this research is conceptualized and articulated through a Business Process Model and Notation (BPMN) diagram, as shown below [Figure 8].

Figure 8: Action-based SE Rule



Source: Developed by Researchers, 2026

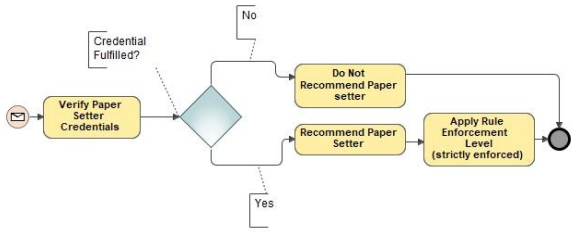
Rule Enforcement for Recommendation of Paper Setter

Accordingly, the above rule is adopted for the recommendation of the paper setter by the Faculty Board.

If <Paper Setter credential> = fulfilled setter requirements THEN recommend. <strictly enforced>

The above rule enforcement ontology can be represented using a BPMN activity diagram, as illustrated below [Figure 9].

Figure 9: Rule Enforcement for Paper Setter recommend



Source: Developed by Researchers, 2026

The condition of this rule requires that the paper setter be a subject lecturer, a visiting lecturer, or another lecturer with relevant subject expertise. When this condition is satisfied, the prescribed action shall be taken, namely the submission of a recommendation to the Faculty Board [Figure 9]. The rule shall be applied only upon receipt of the Faculty Board's recommendation. This rule is designated as strictly enforced, which represents the Business Rule Enforcement Level.

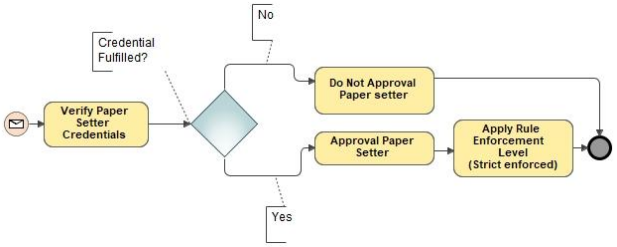
Rule Enforcement for Approval of Paper Setter

Accordingly, the above Action Enable Rule is adopted for the approval of the paper setter by the Senate.

If <Paper Setter credential> = fulfilled setter requirements THEN Approval. <strictly enforced>

The above rule enforcement ontology can be represented using a BPMN activity diagram, as illustrated below [Figure 10].

Figure 10: Rule Enforcement for Paper Setter approval process



Source: Developed by Researchers, 2026

The condition of this rule requires that the paper setter be a subject lecturer, a visiting lecturer, or another lecturer with relevant subject expertise. When this condition is satisfied, the prescribed action shall be taken, namely the submission of a recommendation to the Faculty Board [Figure 10]. The rule shall be applied only upon receipt of the Faculty Board's recommendation. This rule is designated as strictly enforced, which represents the Business Rule Enforcement Level.

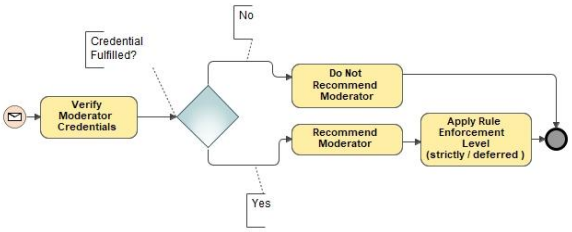
Rule Enforcement for Recommendation of Moderator

Accordingly, the above Action Enable Rule is adopted for the recommendation of the moderator by the Faculty Board.

If <Moderator credential> = fulfilled moderator requirements
THEN recommend. **<strictly enforced> or < deferred enforcement>**

The above rule enforcement ontology can be represented using a BPMN activity diagram, as illustrated below [Figure 11].

Figure 11: Rule Enforcement for moderator recommend process



Source: Developed by Researchers, 2026

The condition of this rule requires that the moderator be a senior academic in the subject area in the same faculty or the other faculty or the university or industrial. When this condition is satisfied, the prescribed action shall be taken, namely the recommendation from the Faculty Board. The

rule shall be applied only upon receipt of the Faculty Board's recommendation [Figure 11]. This rule is designated as strictly enforced or deferred enforcement, which represents the Business Rule Enforcement Level. Here are the deferred enforcement level rules that were applied, along with the senior academic responsible for the task; however, the task was carried out by a junior academic.

Rule Enforcement for Approval of Moderator

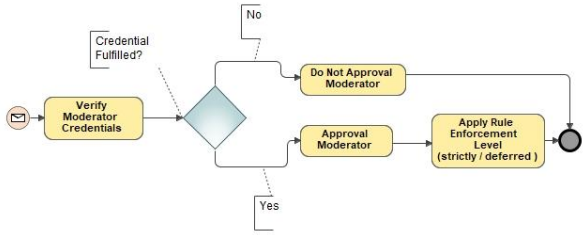
Accordingly, the above Action Enable Rule is adopted for the approval of the moderator by the senate.

If <moderator credential> = fulfilled setter requirements

THEN Approval. <strictly enforced> or < deferred enforcement>

The above rule enforcement ontology can be represented using a BPMN activity diagram, as illustrated below [Figure 12].

Figure 12: Rule Enforcement for Moderator approval process



Source: Developed by Researchers, 2026

The condition of this rule requires that the moderator be a senior academic in the subject area in the same faculty or the other faculty or the university or industrial. When this condition is satisfied, the prescribed action shall be taken, namely an approval from the senate. The rule shall be applied only upon receipt of the approval of the senate [Figure 12]. This rule is designated as strictly enforced or deferred enforcement, which represents the Business Rule Enforcement Level. Here are the deferred enforcement level rules that were applied, along with the senior academic responsible for the task; however, the task was carried out by a junior academic.

Similarly, the ROEESF are defined for the first marking and second marking processes under the SE Procedure Approval phase, encompassing both the Faculty Board's recommendation and the Senate's approval. In addition, the RORESF can be extended to other processes across all Pre–Student Evaluation phases.

Rule Ontology and Rule Enforcement Sub-framework for SE Execution

Under the Student Evaluation (SE) execution process, several sub-evaluation processes are conducted by academic staff members. These processes include execution of summative evaluation, execution of formative evaluation, academic staff attendance, non-academic staff attendance, candidate attendance, and collection of answer scripts. Among these processes in conducting the examination, the researcher develops the RORESF for a selected subset of processes within the SE execution phase, rather than for all identified processes.

Rule Enforcement Sub-framework for staff attendance management

In this context, both academic and non-academic staff are taken into account in the development of the RORESF. Accordingly, a structured and decision-driven workflow is modeled to support systematic rule validation and enforcement.

In this process, staff attendance credentials are initially verified to determine eligibility for entry into the examination hall. If the staff member does not qualify, he/she will not be allowed inside the exam hall. But if the staff member does qualify, his/her presence in the exam will then be recorded by signing his/her attendance on the attendance list. Afterwards, the system will verify if the staff member has multiple entries in his/her attendance. In the event of a duplicate entry, the attendance record is rejected in order to maintain data integrity. If no duplication is detected, the staff member is required to remain in the examination hall until the completion of the examination.

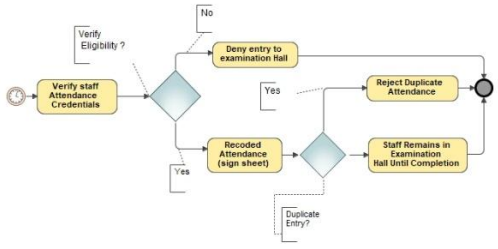
This process ensures controlled access, accurate attendance recording, and compliance with examination supervision requirements. For the staff attendance recording process, both the strictly enforced and post-justified override Business Rule Enforcement Levels are applied. The post-justified override enforcement level is activated in exceptional circumstances, such as the absence of an assigned academic or non-academic staff member, allowing a suitably qualified replacement to be appointed. Such substitutions are subject to approval by the relevant authority after the completion of the examination process.

Accordingly, the above Action Enable Rule is adopted for the recording of the staff attendance in the examination hall.

If <examination staff credential> <> fulfilled attendance requirements
THEN deny entry to examination hall else Approve to entry to examination Hall.
Eles-if < Duplicate staff credential ><> fulfilled attendance requirements
Then rejected entry to examination hall else Staff Remains in Examination Hall Until Completion.
<strictly enforced> and < post-justified override>

The graphical representation of the rule enforcement ontology is presented below [Figure 13].

Figure 13: Rule Enforcement Sub-framework for staff attendance management process



Developed by Researchers, 2026

Rule Enforcement Sub-framework for candidate attendance.

Multiple rules govern the arrival of candidates at the examination hall. These rules include verification of the candidate's eligibility with respect to the relevant year of study, course unit, subject name, examination time, and designated examination venue. Upon completion of this verification process, only candidates who are confirmed as eligible are permitted to enter the examination hall.

Accordingly, the above Action Enable Rule is adopted for the recording of candidate attendance in the examination hall.

If **<verify examination** ***credential*****> =** ***fulfilled requirements***
THEN entry to the examination hall
Business Rule Enforcement Level is **<strictly enforced>**

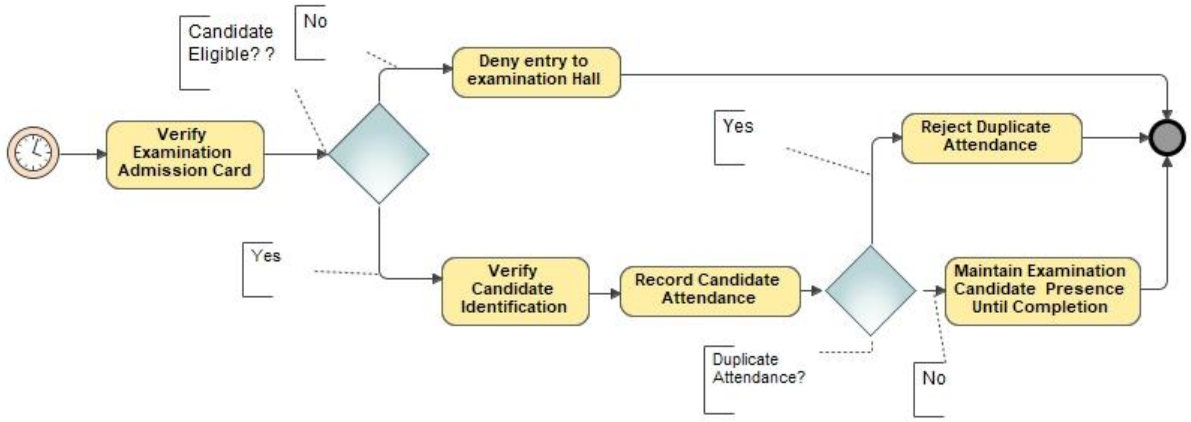
Another rule requires verification of the candidate's examination admission card. If the admission card is available, the candidate's attendance is recorded on the official attendance sheet. If the admission card is not available but the candidate's official identity card is available, the supervisor verifies the candidate against the official attendance sheet; if the eligibility criteria are satisfied, entry to the examination hall is permitted. Furthermore, if the candidate's index number is not listed on the official attendance sheet but both the admission card and official identity card are available, the supervisor may permit entry subject to eligibility verification. In such situations, submission of the admission card and confirmation of the candidate's inclusion in the official attendance records are mandatory either during or after the completion of the examination. These exceptional cases are governed by the post-justified override level of the Business Rule Enforcement Level. Additionally, duplicate verification checks are enforced, and candidates with duplicate attendance records are not permitted to enter the examination hall.

Accordingly, the above **Action Enable Rule** is adopted for the recording of the candidate attendance record.

If **<verify Admission** ***credential*****> =** ***fulfilled requirements***
THEN entry to the examination hall

These exceptional cases are governed by the post-justified override level of the Business Rule Enforcement Level. The graphical representation of the rule enforcement ontology is presented below [Figure 14].

Figure 14: Rule Enforcement Sub-framework for Candidate Admission recode process



Source: Developed by Researchers, 2026

Rule Enforcement Sub-framework for collection of answer scripts

The last section of the execution phases of the SE process. The collection of the answer script process is activated at the end of the examination process in the SE. This represents the rule enforcement workflow for the collection and handling of answer scripts at the conclusion of an examination. The process begins with a decision point that determines whether the examination has officially ended. If the examination has not ended, candidates are instructed to continue writing. Once the examination concludes, authorized invigilators or supervisors initiate the collection of answer scripts from all candidates.

Following collection, the answer scripts are systematically verified against the official attendance records and candidate details (index no) to ensure completeness and validity. In case there are deficiencies, such as missing scripts, "inconsistent script and attendance cards," or "not indicate index no.," the deficiencies are formally documented and reported to the immediate supervisor for appropriate action.

If there are no discrepancies found, these scripts are then counted and matched with the attendance register in order to verify that the total number of scripts is equal to the total number of candidates attending. Then later, these scripts will be packed and secured for preparation for official processing. The final process for obtaining the answer scripts will be when these packed scripts with relevant documents are submitted to the examination department.

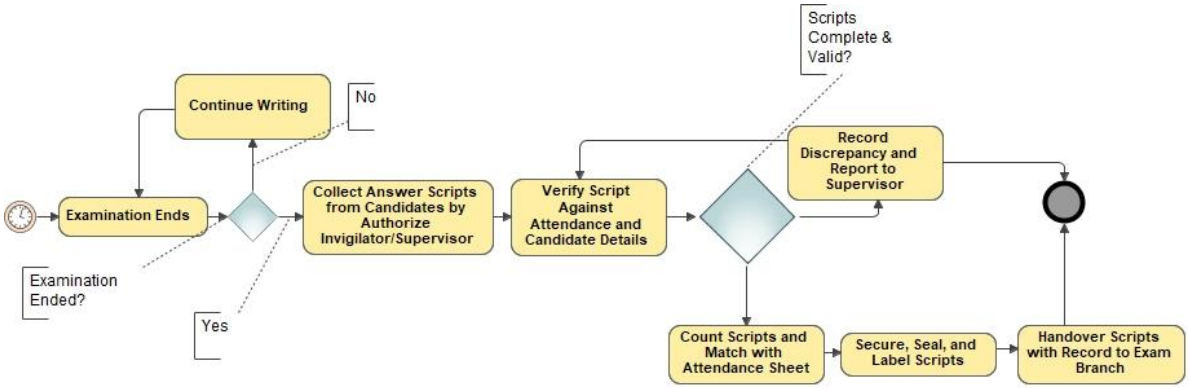
This process thus not only ensures procedural integrity but also traceability of answer scripts in regard to their post-examination handling process, thus ensuring adherence to examination governance policies.

Accordingly, the above Action Enable Rule is adopted for the collection of the answer scripts.

If <verify time credential> = fulfilled requirements
THEN collection of the answer scripts
If <verify answer script credential> = fulfilled requirements
THEN Seal and Label scripts

These exceptional cases are governed by the <strictly enforced> level of the Business Rule Enforcement Level. The graphical representation of the rule enforcement ontology is presented below [Figure 15].

Figure 15: Rule enforcement for the collection of answer script process



Source: Developed by Researchers, 2026

Rule Ontology and Rule Enforcement Sub-framework for post-SE

Upon completion of the SE Execution Phase, the Post-SE Phase is initiated as the final stage of the SE. This phase comprises multiple sub-evaluation processes, which are organized into three primary process groups: Academic Staff Post-SE, Candidate Post–Student Evaluation, and Non-Academic Staff Post–Student Evaluation. Within the Post-SE Phase.

Rule Ontology and Rule Enforcement Sub-framework for Academic Staff Post-SE

In the Academic Post-SE Phase, two primary subcategories are identified: Marking of Answer Scripts and Marksheet Production. The Marking of Answer Scripts subcategory comprises two subprocesses: First Marking of Answer Scripts and Second Marking of Answer Scripts. Similarly, the Marksheet Production subcategory includes the subprocesses Final Marksheet Production and Verification of the Final Marksheet. For this phase, the RORESF are developed and applied specifically to the Marking of Answer Scripts only and First and Second Marking of Answer Scripts, considered together as a unified subprocess. and, not to discuss rules ontology and rule enforcement for the process of "Marksheet Production".

Rule Ontology and Enforcement for First /Second Marking of Answer Scripts

The First Marking and Second Marking of answer scripts both employ the same type of Rule Ontology and Rule Enforcement mechanisms. Therefore, the discussion of these subprocesses is presented together.

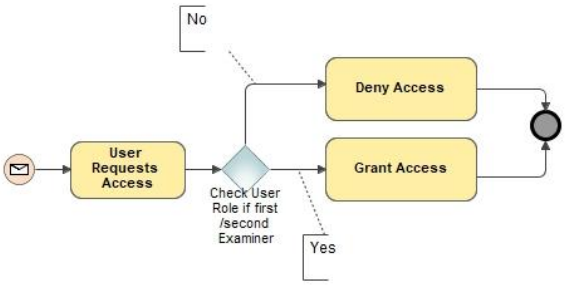
Request Access to answer script:

Accordingly, the above Action Enable Rule is applied to govern this Marking of Answer Scripts process, as outlined in the following:

IF User role= =First examiner /second examiner
THEN Grant to access answer scripts
ELSE deny access

The graphical representation of the rule enforcement ontology is presented below [Figure 16]

Figure 16: Rule enforcement for the First /second request access to marking



Source: Developed by Researchers, 2026

These exceptional cases are governed by the <strictly enforced> level of Business Rule Enforcement.

If the user is assigned the role of First Examiner/second Examiner, the system grants authorization to access the relevant answer scripts, thereby enabling the examiner to perform evaluation and marking responsibilities. Conversely, if the user does not hold the First Examiner/second Examiner role, access to the answer scripts is denied in order to preserve the confidentiality, integrity, and controlled handling of examination materials. This ensures that only authorized individuals can access sensitive assessment data. Therefore. This plays an important role in ensuring that the issue of academic integrity and accountability is addressed.

Authorization rules:

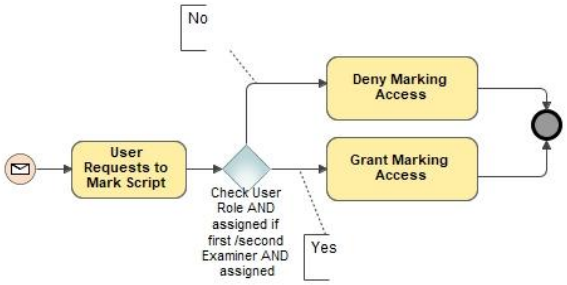
Thus, the above **"Action Enable Rule"** will be applicable for regulating this process according to the following:

IF User Cadential == "First/Second Examiner"
AND Script cadential == TRUE
THEN
Allow marking Access the relevant answer scripts
ELSE
Deny marking Access

This case is governed by the <strictly enforced> level of the Business Rule Enforcement.

The above rule enforcement ontology can be represented using a BPMN activity diagram, as illustrated below [Figure 17].

Figure 17: Rule enforcement for the First /second authentication



Source: Developed by Researchers, 2026

Once the permission to view the answer scripts has been obtained by the First and/or Second Examiner, the process moves to the verification of the authorization status for the answer scripts to be accessed. Based on the rules set for the answer script authorization, the process authenticates the answer script identifier and the answer script ownership information (such as ID, Name, and number of scripts for the answer scripts). If the answer script authorization conditions have been met, the examiner can proceed to mark the answer scripts.

Completion rules:

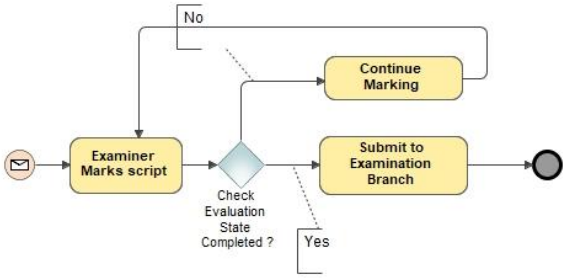
Thus, the above "Action Enable Rule" will be applicable for regulating this process according to the following:

IF Evaluation_Status == "Completed"
THEN Submitted to Examination Branch
ELSE Marking continues

This case is governed by the <strictly enforced> level of the Business Rule Enforcement.

The above rule enforcement ontology can be represented using a BPMN activity diagram, as illustrated below [Figure 18].

Figure 18: Rule enforcement for the First /second completion



Source: Developed by Researchers, 2026

Upon completion of the evaluation by the First and/or Second Examiner, the system verifies the total number of evaluated answer scripts. Subsequently, the examiner records the marks awarded for each individual question in the official marksheet, performs the requisite calculations, and finalizes the results, subject to the condition that the **Evaluation Status** is marked as Completed. Following finalization, the evaluated answer scripts are securely sealed and formally handed over to the Examination Branch in accordance with established institutional procedures. The system shall automatically generate and dispatch notifications to the examiners, as well as to the relevant head of the examination branch, Heads of Departments, and the Dean of the Faculty.

Rule Ontology and Rule Enforcement Sub-framework for non-academic staff post-SE

Among these, three main subprocesses have been identified: Generation of the Displayed Results Sheet, Production of the Degree Certificate, and Issuance of Candidate Notifications. In this phase, the RORESF have been developed for the generation of the displayed results sheet and production of the Degree Certificate; however, they have not been developed for candidate notifications in this phase at this stage.

Rule Ontology and Enforcement for Displayed Results Sheet.

After the Final Marksheet Production and Final Marksheet Verification by the Head of Department, the documents are submitted to the Examination Branch, thus beginning the process of preparing the Displayed Results Sheet. First, access to the system is obtained for the nominated staff member in the Examination Branch. After accessing the final marksheet, the staff member starts the process of preparing the Displayed Results Sheet. During the preparation of the Displayed Results Sheet, the Action Enable Rule Ontology and the Business Rule Enforcement layer are developed and applied to each constituent process involved in the generation of the Displayed Results Sheet.

Authorization rules:

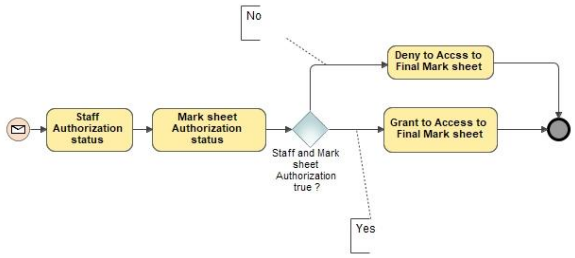
Thus, the above "Action Enable Rule" will be applicable for regulating this process according to the following:

IF Staff Cadential Status AND Marksheet Status == TRUE
THEN
Grant the Access relevant final marksheet for relevant staff member
ELSE
Deny Access to Final marksheet

This case is governed by the <strictly enforced> level of the Business Rule Enforcement.

The above rule enforcement ontology can be represented using a BPMN activity diagram, as illustrated below [Figure 19].

Figure 19: rule enforcement for the authentication for display result sheet



Source: Developed by Researchers, 2026

This rule defines an access control mechanism governing the authorization to access the relevant final marksheet. If the "Staff Cadential Status" is set to TRUE, it indicates that the staff member has been duly authenticated and possesses the necessary institutional privileges to access examination-related records. Simultaneously, if the "Marksheet Status" (final marksheet subject name, Subject ID, Year, Semester, etc) is also TRUE, it confirms that the final marksheet has been officially verified and approved for access within the system. When both conditions are satisfied, the system grants the authorized staff member access to the relevant final marksheet. If either condition is false, access is denied to ensure security, confidentiality, and data integrity.

In this context, a strictly enforced level of Business Rule Enforcement is applied to ensure compliance and governance within the evaluation process. However, the Examination Registrar is permitted to operate under a deferred enforcement rule in exceptional circumstances, such as when the relevant authorized staff member is unavailable to complete the required authorization or in cases of operational emergency. This controlled exception ensures continuity of examination-related processes while maintaining institutional accountability and regulatory oversight.

Rule Ontology and Enforcement for Production of the Degree Certificate

The production of the degree certificate is a process that involves producing official documents that will prove that the student has successfully completed his or her studies. The process can be undertaken only after all the evaluation stages have been completed and approved. Degree certificates are used as legally binding proof of academic success and achievement by students.

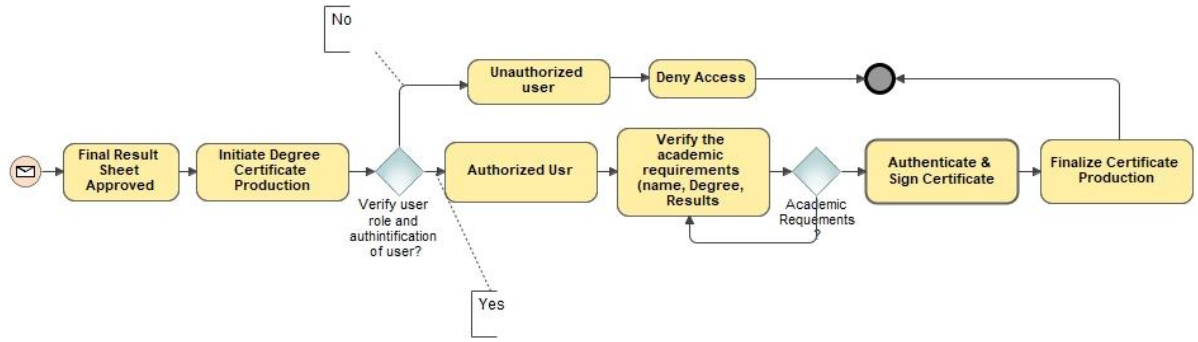
Thus, the above **"Action Enable Rule"** will be applicable for regulating this process according to the following:

IF User Credential == True credential AND academic status Verified == TRUE
THEN
Allow to generate the certificate for the individual candidate
ELSE
Deny Access

This process is governed by the <strictly enforced> level of Business Rule Enforcement.

The above rule enforcement ontology can be represented using a BPMN activity diagram, as illustrated below [Figure 20].

Figure 20: rule enforcement for the production of degree certificate



Source: Developed by Researchers, 2026

Following the completion and formal validation of the final result sheet of the final examination, the production of the degree certificate is Prepare combing with non-academic staff and administrative staff. The Certificate Preparing is governed by a set of explicitly defined business rules that regulate authorization, verification, and procedural execution.

The authorization rule is defined as follows:

"User Credential = = True credential AND academic status Verified = = TRUE"

Within this rule construct, multiple action-enabling sub-rules are evaluated. The condition "User Credential" is used to identify the user credential for given the user permission for preparation and processing of the degree certificate. This includes verification of assigned staff members who is responsibility person in the institutional authorities such as the examination branch, Registrar, and the Vice-Chancellor, whose authenticated approvals and signatures are mandatory for certificate validation.

Simultaneously, the criterion "Academic status verified" guarantees that all academic requirements have been fulfilled. Such a verification requires matching of the candidate's name with the approved degree course and the final result sheet. The certificate production process is accomplished only on fulfillment of all the stated conditions. In case any one of the stated conditions is not fulfilled, then access to the system is denied. The above Business Rule Enforcement mechanisms are represented using the following BPMN diagram [Figure 20].

Rule Ontology and Rule Enforcement Sub-framework for Candidate post-SE

RORESF development is done in the final stage of the framework where the Candidate Post-Student Evaluation Process is conducted. The Candidate Post-Student Evaluation Process is categorized into three broad categories, which include Requesting Intermediate Results, Requesting Final Results, and Requesting Other examination-related documents. As far as the current research study is concerned, RORESF development is done for the former two categories of Requesting Intermediate Results and Requesting Final Results.

Rule Ontology and Enforcement for Requesting Intermediate /Final Results

Requesting Intermediate and Final Results are two sub-processes within the Post-Student Evaluation (Post-SE) process whereby students can obtain access to their intermediate, partial or final academic results prior to the release of the intermediate or degree certificates. The two sub-processes facilitate transparency and timely sharing of academic results in the SEL.

Both sub-processes begin with the candidate and share similar business rules. Like all other processes, the two use similar authorization, validation, and access control mechanisms to make sure that the accuracy and regulatory compliance of the academic information is guaranteed.

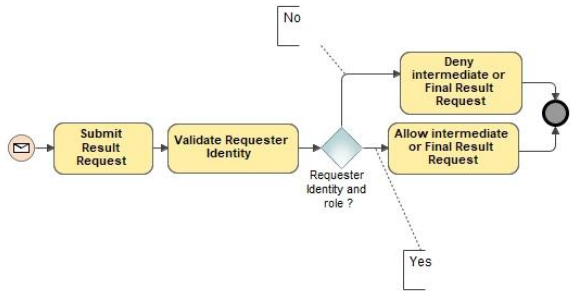
Thus, the above **"Action Enable Rule"** will be applicable for regulating this process according to the following:

Approved Candidate Rule:

IF Candidate Credential = = True AND Requested Status ==True
THEN
Allow to intermediate /final Result Request
ELSE
Deny Request

This process is governed by the <strictly enforced> level of the Business Rule Enforcement. The above rule enforcement ontology can be represented using a BPMN activity diagram, as illustrated below [Figure 21].

Figure 21: rule enforcement for the intermediate and final result



Source: Developed by Researchers, 2026

Initially, the candidate is required to complete and submit the relevant institutional application for requesting academic results. Upon submission, the system evaluates a predefined access-control rule, expressed as:

Candidate_Credential == True AND Requested Status == True

This rule is applicable to the candidate's qualification for seeking either intermediate or final academic results. In this context, this rule authenticates the candidate's qualifications by verifying the candidate's unique identification via an authentication process. Further, this rule also checks the "Requested Status" to determine whether the request is for either intermediate or final results.

If this condition is met, the request is granted access, thereby allowing access to the academic result information. In the event that either of these conditions is not met, the request is denied access. This rule-based system facilitates institutional governance by ensuring secure authorization and maintaining the confidentiality of the access control within the post-student evaluation process.

Research Limitations

This study was undertaken as a pilot study with the objective of developing a Rule Ontology and Rule Enforcement sub-framework. The study was undertaken on one of the processes in the SEL, namely the pre-SE phase, the SE execution phase, and the post-SE phase. These processes were used to design and implement the initial version of the Rule Ontology and Rule Enforcement sub-framework, with the objective of expanding this framework to cover the entire process of the SEL. The study findings show that this theoretical framework offers a solid foundation for the design and implementation of an IT-based solution that facilitates and accelerates the SEL in university settings.

CONCLUSION

This research proposes and validates a comprehensive RORESF for SEL. The proposed framework presents a systematic way of integrating governance policies and enforcing institutional rules on important student evaluation processes, thus improving the level of compliance, transparency, and accountability in the management of educational service activities.

The use of the Action Enable business rule classification and the clear incorporation of the Business Rule Enforcement Levels ensure the separation of rule semantics from rule enforcement strategies, thus allowing the institution to effectively manage the level of regulatory control while at the same time ensuring flexibility, especially in unique or time-sensitive academic situations. The use of BPMN-based representations ensures improved interpretation and implementation of the proposed framework by system designers and developers.

The proposed framework's applicability to selected Pre-SE, SE Execution, and Post-SE processes ensures the framework's flexibility for use in different student evaluation scenarios, including the monitoring of the SE process. Although the proposed framework only addresses some student eval-

uation processes, the proposed rule ontology and rule enforcement mechanisms can easily be generalized to other student evaluation activities and other educational scenarios. In conclusion, the proposed research contributes to the development of a rule-based intelligent SEL and can be of immense use to higher learning institutions seeking to improve the level of governance and academic integrity while at the same time improving the level of automation on student evaluation activities.

This study focuses specifically on SEL. However, future research may extend the proposed ontology-driven rule enforcement framework to other areas of student-related activities and administrative processes within university systems, such as student admission, course registration, attendance management, academic advising, internship management, and graduation processing.

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