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Application of Context-Aware Business Intelligence Framework in Determining Riskiness of Academic Modules Within Tertiary Institutions

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Abstract: This study shows the researchers efforts to determine the riskiness of academic modules at a South African University. In determining the modules at risk, the researchers used a hybrid of sequential and cyclical methodological approaches based on a context-aware business intelligence framework. The risk indicators derived from academic module enrolment data elements were weighted and aggregated to determine the riskiness of a module. The results showed that the riskiness of a module can be zero, weak, strong and extreme. Depending on the riskiness of a module, the institution can determine the appropriate intervention strategies for students to succeed in passing the module. This research proves to be essential for program and module reviews which are important quality assurance exercises within the South African higher education institutions.

Key words: Risk modules, business intelligence, degree of difficulty, content knowledge, strong, institution

INTRODUCTION

The expression "content knowledge" denotes to the corpus of knowledge and information that the students are anticipated to learn in a specified subject, module or content area (Loewenberg *et al*., 2008). In this study, content knowledge represents the facts, concepts, theories and principles that undergraduate students at a South African University are taught and learnt in identifiable academic courses. The facts, theories or concepts engraved in the different academic modules at a South African University, herein referred to as modules have different degrees of complexity. The use of the term "content knowledge" has matured considerably in recent years, partly because educators now ordinarily use the expression as a shorthand means to pronounce a useful technical difference amongst "knowledge" and "skills" (Anghel, 2015; Loewenberg *et al*., 2008). The riskiness of a module at a university is determined by varied factors which are herein referred to as module risk indicators.

This study focusses on the riskiness of the module rather than focusing on the students at-risk which consider cognitive and social risk indicators (Mehta, 2014; Worley, 2007). The expression "at risk" is employed frequently to describe students who are academically performing dismally and it has a resilient perspicacious meaning. In that regard, the term has no dependable definition and can be regarded as stigmatizing student groups. Nonetheless, it is extensively used within the cognition and education fields. Despite the flexibility, it is still imperative to have a standard or a reference point for a clear communication of what "at risk" module means (Trends, 2006). This study emphasizes some of the issues surrounding the concept. The information obtained on the riskiness of a module should assist a university in one of its core business mandate which is teaching and learning. The other issue associated with the riskiness of a module is to conceptualize it methodologically. In that regard, it is important to conceptualize the modules at risk at a university using theoretical and practical foundations of Business Intelligence (BI).

Context-aware business intelligence framework: Mutanga (2015) defined a Context-Aware Business Intelligence Framework (CABIF) as a situated set of concepts, techniques, tools, ideas or facts that provide support for business intelligence initiatives within the South African Higher Education Institutions (SAHEIs). In this research, we have also drawn up a detailed CABIF which shows an example of a practical decomposition of CABIF in relation to some of the key SA higher education core business areas (Fig. 1).

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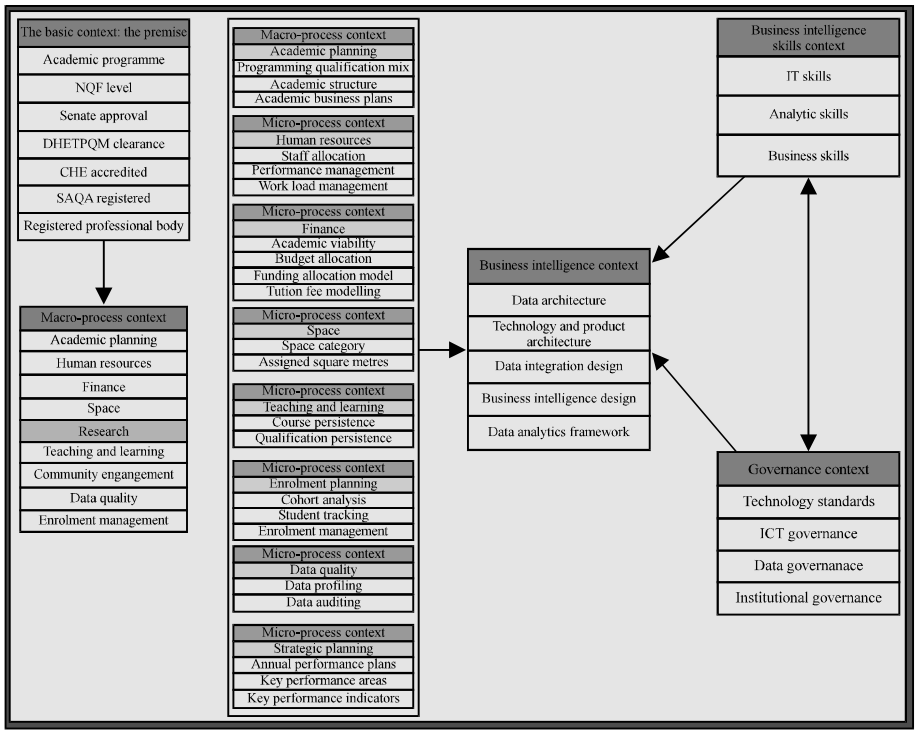

Fig. 1: Detailed Context-Aware BI Framework (CABIF) for SAHEIs

The CABIF in the SAHEIs, requires BI practitioners to know and understand various institutional core business contexts (Mutanga, 2016). According to Mutanga and Kadyamatimba, the CABIF starts with the basic context which requires the planning and approval of academic qualifications at an SAHEI. The process context immediately follows, depicting macro-process BI contexts and micro-process BI contexts. Both micro and macro process contexts are related to direct business processes within the institution. To get value from the BI system, the CABIF has the business intelligence context which has the data architecture, technology and product architecture, data analysis framework and the design of the BI application. To achieve all the elements of the BI context of CABIF, there is a need of a triad of skills, i.e., IT skills, analytic skills and business skills (Mutanga, 2015; Mutanga, 2016). The triad of these set of skills, form the business intelligence skills context of CABIF. Information assets, ICT and business processes need to be governed methodologically at each SAHEI. Identifying the governance context of CABIF (Mutanga, 2016) argued that it is crucial for most of the contexts of the CABIF. The BI design and implementation itself rely on the various governance frameworks, mechanisms and principles in place. This study addresses four research questions, objectives and the research methodology used to identify modules at risk at a given South African University.

Research aim and objectives: This research was aimed at development of a mathematical metrics that determine the riskiness of an academic module aa given University. The following were the objectives:

- Identify modules at risk at the university
- Distinguish different risk indicators for academic modules at the university
- Develop standard formula for calculating the riskiness of an academic module at the university
- Identify possible use of the information obtained from modules at risk within the university

Research questions: A set of questions to guide the research were proposed as follows:

- Which academic modules are at risk within the university's current programme qualification mix or academic structure?
- What are the different indicators that can be used to identify at risk modules within the university?
- What standard formula can be used to calculate the riskiness of a module within the university?
- How useful is the riskiness of a module to the core business of the university?

At most Higher Education Institutions (HEIs) within South Africa, a formal university-wide standard for

academic performance determines a student's academic standing. This is clearly shown by institutional efforts to establish Centres for Higher Education Teaching and Learning. HEIs endeavour to have students with good academic standing, semester by semester within their individual programs in order to achieve high success rates and throughput rates. Although, there are various factors that contribute to academic performance of students (Anghel, 2015; Mckee and Caldarella, 2016), this study will focus on the degree of complexity of a module and elucidates on its riskiness. The theoretical framework will elucidate on the theoretical and practical foundations of modules at risk within a South African University.

Theoretical framework: The term "at risk" has been associated with academic performance of students with the grades of summative and formative assessments obtained by students being the determinants of the academic riskiness of students (Mckee and Caldarella, 2016). Most institutions offer academic support services to academically at-risk students. The standards to identify at-risk students vary from institution, faculty, department or school and usually reflect different programs in the curriculum (Fryer *et al*., 2012; Worley, 2007). According to company, faculties use different scales to distinguish academically at-risk students. As an example, a student might be academically at risk if any assessment is below 50% (Fan *et al*., 2011). This usually depends on institutional priorities and definitions of the academic risk indicators.

Academically at-risk students: The identification of academically at-risk students has focused primarily on factors that influence the student's test scores (Anghel, 2015; Mehta, 2014). Some studies have focused on the correlations between student demographics and their test scores and some examining student's substance abuse and their academic performance (Anghel, 2015). The studies on student's substance abuse concluded that the majority end up academically excluded or dropout from the academic programs. The studies for academically at-risk students focus mostly on bivariate relationships among the different risk factors. In the process of identification of students who are likely to be academically at-risk, tracking systems are usually employed in most institutions. The tracking systems are categorised as early warning systems, early alert systems, student tracking systems, etc. Student tracking systems are therefore, equipped with tools to review the student's academic performance and grades across all courses and reports on students who are likely to be academically at-risk. As indicated it is also important to assess the student's performance in historically challenging courses (Fan *et al*., 2011) argues that it is more efficient and effective to evaluate student performance in select courses, especially for large module enrolments.

Degree of complexity of an academic module: Complexity has been demarcated literally based on the appearances of "the behaviour shown by a complex system" as indicated by Johnson (2009). Complexity is not easy to define as it can signify various things to diverse people. In the scientific community, there is yet an exclusive definition of complexity (Johnson, 2009; Teqsa, 2012). Several studies unearth the mystic ingredients which render something complex as contrasting to just being intricate and show how complexity is profoundly entrenched in the everyday life (Johnson, 2009; Teqsa, 2012) identified that one of the problems in tackling complexity matters has been sanctifying the instinctive conceptual distinction amongst the huge quantity of inconsistencies in relationships extant in random collections and the sometimes large but smaller, number of relationships between elements in systems. By definition, "complexity science is the study of the phenomena which emerge from a collection of interacting objects" (Johnson, 2009).

Complexity can be associated with the degree of an academic module. An academic module fits into the definition of a complex system as it consists of a set of interacting theories, facts and principles which in this study has been previously defined as subject content knowledge. This study looks at the degree of complexity of an academic module, hence, it refers to the at-risk module. The degree of complexity of a module is not looked at based on the complexity of the content that constitute the module, rather this study looks at it based on attributes that constitute module enrolments. The academic module as a system, contains an assembly of numerous intermingling objects or "agents" (Johnson, 2009; Weaver, 1948). The attributes that constitute module enrolments are herein referred to as module risk indicators. The researchers are of the view that when these attributes are aggregated they bring forth the degree of complexity of a module, hence, the "riskiness" of the module.

Module risk indicators: In the education field, there is no such thing as an easy academic module as many researchers have identified different aspects to consider in student academic performance (Anghel, 2015; Mehta, 2014; Johnson, 2009). The academic performance of a student has been measured by their social, cognitive and emotional strengths including internal institutional

academic support initiatives (Fryer *et al*., 2012; Teqsa, 2012). As to which is the most difficult academic module within an institution is an impossible task to handle (Loewenberg *et al*., 2008). The reason is that, there are many competing factors which may need to be weighed to determine the complexity of a module. What is important is to determine a set of indicators or factors that determine the complexity of a module. The complexity of a module in this case, determines the probability that a student can fail that module. The probability of a student to fail a module determines the riskiness of that module.

A risk factor or a risk indicator is a measure used frequently in management to designate how risky an activity is Anghel (2015). The risk indicator is also an indicator of the possibility of future adverse impact. In this study, the risk indicator of a module at a South African University is a possible measure that designates the possibility of a module to be failed by a quantum of students. The use of a system of indicators in assisting in decision making vary from one industry to another (Saqib and Siddiqi, 2016). This largely depends on their objectives and scope and in determining indicators for modules at risk, the factors that can predict the likelihood for students to fail a module play important role (Mckee and Caldarella, 2016). One issue to consider in the usage of a system of indicators for determining the riskiness of a module is to identify the weightage of each of the indicators (Saqib and Siddiqi, 2016).

Determination of weightings for module risk indicators: The determination of the weightings factors for risk indicators for modules, starts with the consideration of factors that can influence the likelihood for a student to fail a module. According to Saqib and Siddiqi (2016), the basis is to research down on a structure which determine the attributes that can affect academic performance. It is also notable that, each of the attributes can be decomposed to lower levels of granularity to achieve completeness. The decomposition of the attributes of the module risk indicators can act as gateways to determine the Weighting Factors (WFs) for each module risk indicator. Within the academic world, it is important to note that only specific academic risk indicators are directly measurable (Anghel, 2015; Saqib and Siddiqi, 2016). Usually, the risk indicators that are directly measurable are the lower level atomic attributes, related to the module data. The values of each of the identified risk indicator are then aggregated by some standardised means or formula to derive to a quantitative value that determine the overall riskiness of a module (Saqib and Siddiqi, 2016). In developing the meta-schema for the aggregation of the weighting factors for the module risk indicators, the focus was showing how each academic module is doing compared to the others. The aggregation should convey objectively to a South African University management which are the problem modules and to provide meaningful input to decision making processes in improving the pass rates for each module. The lesson one can draw up from Saqib and Siddiqi (2016) is that each indicator has a different degree of impact on the aggregated risk of a module.

MATERIALS AND METHODS

The determination of the riskiness of a module at the university, followed a hybrid of sequential and cyclical methodological approaches. The sequential nature of the methodology is indicated by the logical sequence of steps followed to determine the riskiness of a module. The cyclical or the iterative nature of the methodology indicates the continuous review of the steps and the risk indicators to list the riskiness of a module. Figure 2 shows the methodological approach followed to determine the riskiness of a module at a South African University. The methodology included determining the module risk indicators, determining the measurement of the module risk indicators, developing the weighting factors of the module risk indicators, aggregating the weighted module risk indicators and listing the module riskiness of the university academic modules.

The quality of the module risk indicator was not of primary concern as prior to determining a module risk indicator a series of tests were done. These tests included data availability for the indicator, data quality, manipulability of the module risk indicator, amenability to set objectives and the positive and negative measures. The indicators that were selected and had passed the selection criteria would be aggregated to reveal the riskiness of the module within the university. The mappings and the determination of modules at risk business process, required the researchers to report on the modules at risk using the reporting tools of the BI system at the university. These are the BI tools which present the analytics subjected to the BI data architecture. The analytics assisted in identifying the patterns and anomalies in the data, it stimulated the researcher to pose and answer further questions about the module risk indicators. The determination of modules at risk at the university using CABIF is shown in Table 1.

Determination of module risk indicators and data collection: The basis for determining the risk indicators of a module at the university, started by developing common data elements that could be measured and monitored.

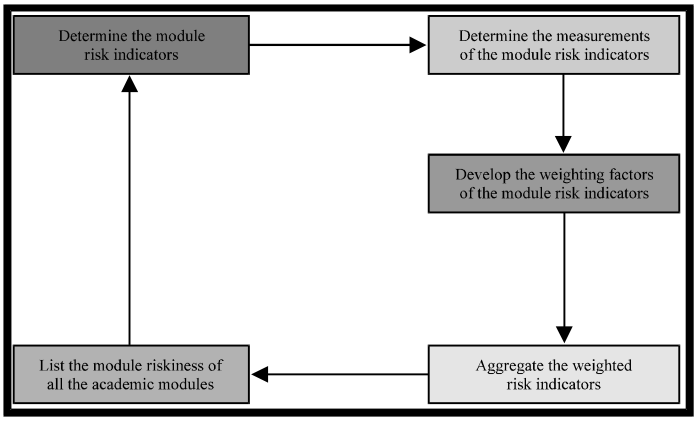

Fig. 2: Sequential and cyclical methodological approach to determine modules at risk

Table 1: CABIF contexts for determining modules at risk at a South Africa University

CABIF context	Description
Basic context: Premise	Academic module enrolments
Process context: Macro-activities	Teaching and learning-programme review
Process context: Micro-activities	Academic module review
Business intelligence context	Data sources: Data warehouse [SCHEMA] [HEDA DATA WAREHOUSE]; M02V_SUBJECT_ENROLMENTS
Business intelligence skills context	IT skills: Data acquisition, data integration, queries, stored procedures, report building and presentation Analytical skills: Knowledge of analytical algorithms Business skills: Assessment policy, definition of key data attributes related to an academic module
Governance context	Regulatory and compliance requirements: POPI ACT Data governance: Data quality requirements specifications, data cleansing

The assumption considered was that, each module risk indicator can have a subjective influence on the other risk indicator, irrespective of its data structure and type. The following were the risk indicators drawn up: student count pass rate module repeaters module compulsory flag possible major flag period of study SAQA credits examination admission and examination admission rate. The student count refers to the number of students who fail a module in the baseline year. The number of students who failed included those who failed the module in the baseline year, baseline year 1, baseline year 2 and baseline year 3. The same applies to the pass rates, it included the pass rates for the same years. The reason for choosing those baseline year, down to baseline year 3 was to include the historic performance for the module. The dependence of percentage of repeaters of the module in the same years, refers to the significance of the degree of complexity of the module.

The complexity of the module can also be determined by the level in which it is given in the curriculum. In this case at a South African University an undergraduate module can be given in the 1st year up to the 6th year. A major is a structured sequence of subject content units in a module or field of study. It provides the institution with the opportunity to develop the knowledge, understanding and expertise that will equip the students to move into a rewarding career after graduation or to pursue further studies in a similar area at postgraduate level. The modules at a South African University are compulsory, elective or not. Each module has been attributed a number of credits that determine the number of notional hours attributed to it within the curriculum. The other factor that determined the riskiness of a module was the examination admission rate. Examination admission rate was also considered to be an indicator of the degree of complexity of a module. In the determination of the risk indicators for the modules, the rating of the indicator was key. The data values for each of the risk indicator were considered and these determined the adjustment variation factor that was used to standardise the risk weightings. The risk indicator values and the standardised weightings for the risk factors are shown in this study.

Measurement and weightings of module risk indicators: The measurement and weighting factors of each of the identified module risk indicators were determined by whether it was a leading or lagging indicator, the dependence on other risk indicators and the relative significance of each indicator compared to other risk indicators. Each of the risk indicators had its data values standardised and weighted. The justification and rationale behind the weightings and their variations are explained in the next study. It is important that, the weightings considered past academic experiences with the modules.

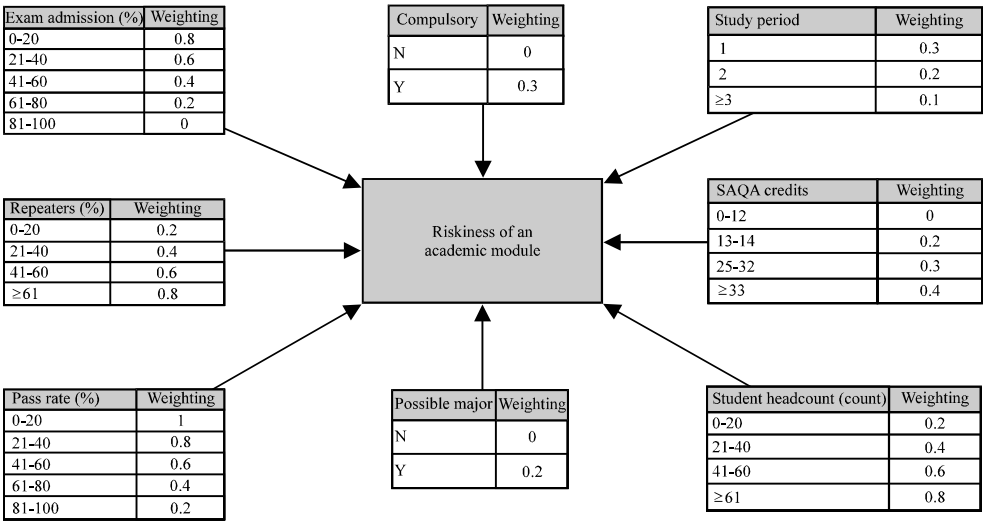

Fig. 3: Module risk indicators and respective weightings

The module risk indicators may also be zero, weak, medium, strong or of extreme impact on the institutional core business of teaching and learning. As mentioned before, each of the weighted risk indicator was standardised and weighted, then aggregated to reflect the overall riskiness of a module. The module risk indicators were as shown in Fig. 3.

Considerations for weighting factors: The following were considerations for the weighting factors:

- Number of students who failed are directly proportional to the weighting, the less the number of students who have failed, the less the weighting
- The module pass rate is inversely proportional to the weighting, the lower the pass rate the higher the weighting
- The number of students repeating in a module is directly proportional to the weighting, the less the number of repeaters, the lower the weighting
- If a module is not compulsory, it's risk impact is almost negligent and if its compulsory its risk impact is weak and has a weighting of 0.3
- Modules in the 1st year of study have an extreme risk impact and hence, they a high weighting factor compared to successive years. Historically more students in the 1st year are likely to fail a module
- The SAQA credits have a direct relationship with the weighting factor. The lower the number of SAQA credits, the lower the weighting factor. The SAQA credits is an indication of the time the student invest on the module within the curriculum
- Examination admission rate is inversely proportional to the weighting factor, the lower the percentage of students admitted sitting in the final examination of module, the higher the weighting

RESULTS AND DISCUSSION

The data analysis started by the summation of all the risk indicators extracted from the M02V_SUBJECT_ENROLMENTS database. The weightage was designed in such a way that, each of the risk indicator has its own impact on the overall module risk:

$$MR = \sum_{i=1}^{16} WFRIi$$

Where:

MR = The overall Riskiness of a Module
WFRI = The Weighted Factor of the Risk Indicator
i = 1, ..., 16

The summation of the weighted factors of each of the 16 risk indicators gave the overall riskiness of a module. The module is extremely at risk if it has the overall riskiness of 11, achieved after the summation of the risk indicators. The conceptualised modules at risk solution was developed as an SQL report within the PowerHEDA environment (Fig. 4) and the filters to the report are shown in Fig. 5.

The University of Venda is one such South African University that has embraced the whole paradigm of modules at risk elucidated in this study. The report is a culmination of linking CABIF and the tenets of one of

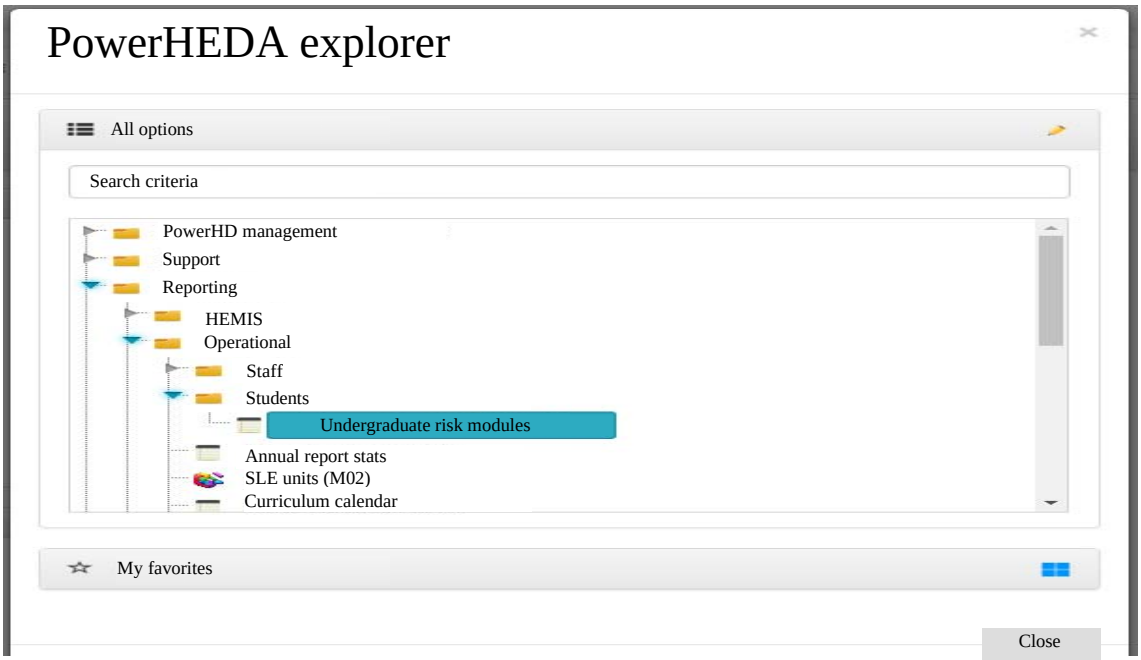

Fig. 4: Implementation in power HEDA

the academic quality assurances processes at South African University and is of great value in the module review business process.

The weightage of each module risk indicator is a strategic intent within the teaching and learning domain and depends on several other factors. In considering the values of the weighting factors for all the risk indicators they were extrapolated between 0 and 1. The final weighted academic risk module is dependent on the normalised or standardised summation of the 16 risk factors. The responses to the research questions are as follows.

Which academic modules are at risk within the university's current programme qualification mix or academic structure? Depending on the overall aggregated weighted risk factors, the resultant module riskiness may result into being zero, weak, medium, strong or of extreme impact on the institutional core business of teaching and learning. A module is extremely at risk if it has the overall riskiness of 11, achieved after the summation of the risk indicators, based on the aggregated weighted risk factors.

What are the different indicators that can be used to identify at risk modules within the university? The subjective interpretation of risk indicators that can make the students pass or fail a module are important data elements to consider when determining the riskiness of a module. As long as the data elements which constitute risk indicators are defined consistently and the weightings standardised and determined scientifically, the riskiness of a module can be determined.

What standard formula can be used to calculate the riskiness of a module within the university? The equation to calculate the riskiness of a module was derived based on the weightage of the identified risk factors and was designed in such a way that, each of the risk indicator has its own impact on the overall module risk:

$$MR = \sum_{i=1}^{16} WFRLi$$

Where:

MR = The overall Riskiness of a Module
WFRI = The Weighted Factor of the Risk Indicator i
i = 1, ..., 16

How useful is the riskiness of a module to the core business of the university? This research contributes to the review of academic programmes at the university. Programme design should "maintain an appropriate balance of theoretical, practical and experiential knowledge and skills" as proclaimed in the criteria for the

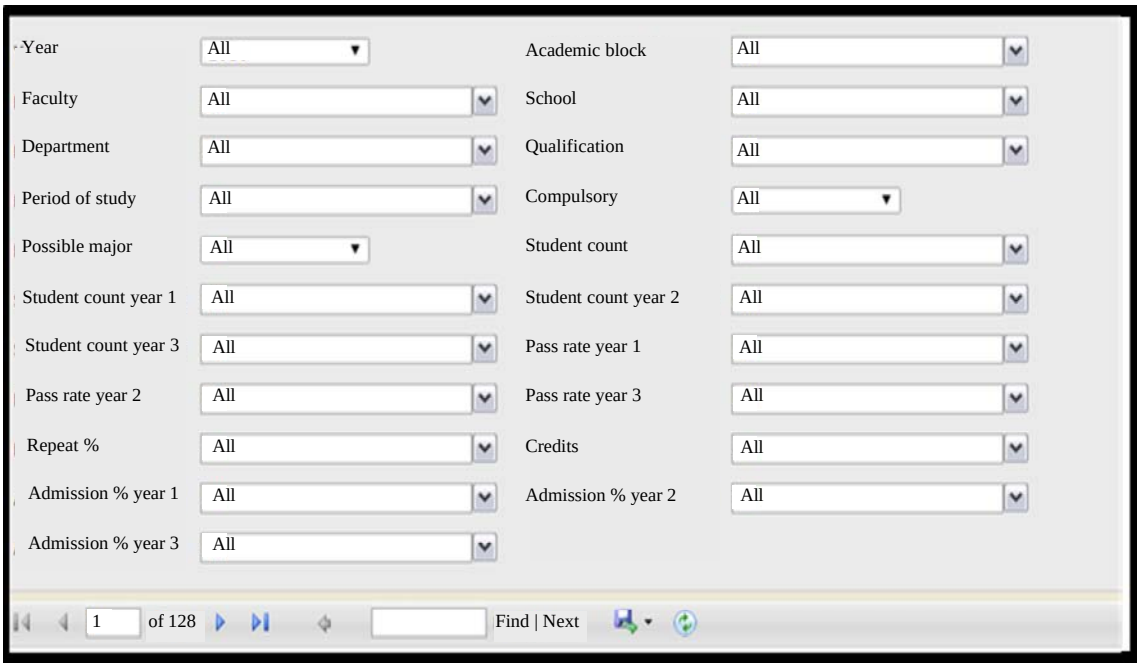

Fig. 5: Power HEDA undergraduate modules at risk report filters

review of academic programmes the university. The understanding and conceptualisation of the riskiness of a module provides pathways to understand if there is sufficient subject content knowledge, aligned to its degree of difficulty.

CONCLUSION

This study contributes to the module performance related information during the reviewing process of academic modules at the university. The researchers used the CABIF to develop and derive a detailed report on module performance using a baseline year. The longitudinal analysis of academic modules at a South African University are studies that looks on how students persist in a module (progression) how they are retained in the module (retention) or whether they are excluded from the module (attrition). Longitudinal module performance analysis assists in academic administration, teaching and learning and enrolment planning activities. In this case, the researchers have chosen the teaching and learning business area and are specifically looking at modules at risk within a South African University.

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