

ERP Transition to e-Commerce: Training for a New Methodology

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Abstract

E-commerce training and teaching at institutions all over the world need to keep up with the pace at which this multi-disciplinary natured subject changes in time, as well as the rate at which business in general is adapting to the Internet. If a course is designed for degree purposes, it is important to have the ultimate goal of the subject material clearly in mind. An e-commerce syllabus for Law students will differ substantially from an e-commerce course for Computer Science students. It is therefore not uncommon to see vast variations in e-commerce syllabi, even in the same discipline, but at different institutions.

E-commerce involves the use of information technology to enhance communications and transactions with all of the organization's stakeholders such as customers, suppliers, government regulators, financial institutions, employees and the public at large. E-commerce is supposed to supply immediate information to the business partners of a particular company which should then lead to a very efficient value chain by which products are manufactured and distributed. This efficiency is believed to be born from the fact that companies can then respond very quickly to their business partner's needs.

The fundamental architecture of e-commerce is also changing rapidly. The complexity of business systems and the difficulty of building connections between the business systems of individual companies have led to a variety of intermediaries and hybrid solutions in the world of e-commerce.

It is evident from the results presented in this paper that the new Prism Methodology, a commercial e-transformation product of ITelligence, Cincinnati, Ohio, can have a lasting impact on the implementation of e-commerce applications in the ERP environment through a creative approach allowing for a bigger focus on the human constructs rather than the system constructs. Another fundamental concept that will allow for a new paradigm is the concept of re-usability of business processes, functional and technical components. Pre-Project activities, as part of such a methodology will ensure that the organization is ready to execute such a project with absolute conviction driving out all aspects of risk.

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ology will ensure that the organization is ready to execute such a project with absolute conviction driving out all aspects of risk.

This article also indicates the main features, as well as expected benefits of the Prism methodology as an example of e-commerce technological application.

Keywords: e-commerce, e-business, enterprise resource planning, informa-

tion technology, business systems, change management, Prism methodology.

Introduction

E-commerce can be defined as the buying and selling of information, products and services with the assistance of computer technology and the Internet (Greenstein & Feinman, 2000). This basically involves the exchange of electronic information between parties, normally followed by the exchange of goods and payment transactions. In the conduct of commerce many differing activities might occur. Some of the functions are marketing, interaction with clients and suppliers, interaction with government, acquisition of products and the sales forthcoming of these events.

E-commerce can also be defined as the conduct of transactions by electronic means. The integration of e-commerce and normal business processes is supposed to supply immediate information to the business partners of a particular company (Greenstein & Feinman, 2000). This should then lead to a very efficient value chain by which products are manufactured and distributed. This efficiency is believed to be born from the fact that companies can then respond very quickly to their business partner's needs. The absolute desire of organizations to achieve vastly improved integration between business processes led to the development and enhancement of Enterprise Resource Planning (ERP) systems during the last decade of the previous century. The exponential expansion of Internet technologies is sometimes hard to follow and needs dedication and commitment from all players, whether they are participating for commercial reasons or studying the academic merit of e-commerce.

Students in Information Systems, Computer Science and other computer related areas must be well informed on these new technologies. Courses offered for people in Industry and persons who enter on more advanced tertiary studies often concentrate on e-commerce and e-business due to the demand from the business world in general. (For the purposes of this paper, e-commerce will be considered to be the sub-set of e-business, mostly dealing with virtual transactions on the Internet (Turban & King, 2003)).

All too often the impact of a new technology is overlooked if a business cannot adapt fast enough to take full advantage of first moves. It is therefore important for students, as the workers of the future, to understand electronic business and its implications to have the necessary knowledge and skills they require to be valuable to any organisation in this age of globalisation (Jenkins, 2000). It is also important to optimise and try to satisfy the needs of the different stakeholders in this learning process: the students, the lecturers and the needs of businesses involved with e-commerce (Dash, 1999).

The wide range of methodologies and disciplines that form the foundation of an e-business course can make the design and ultimate delivery of such a course quite problematic. In the case of the University of Cape Town (UCT, South Africa), the Electronic Business module was designed as a first semester module in the final year for the three year B.Com (Information Systems) degree. This course was presented since 1999 and has been updated yearly with new information and new practical work to keep with the fast pace of change in industry. Students already have a solid understanding of Information Systems in general (including some e-Business aspects) and are in the final stages of rounding up and delivering their third year practical project. As these projects became more dependent on Internet technologies, more web programming projects were built into the practical part of the e-commerce course. Course related information is available at: <http://www.commerce.uct.ac.za/InformationSystems/Courses/INF3014F/outline.asp>.

This paper deals with some of the aspects of technologies in the e-commerce scenario that often do not receive the correct amount of attention in industry, as well as in the training of Information Systems students. The Prism Methodology, a commercial product of the ITelligence Group in the USA, is chosen as an example of a new technology that can bring huge benefits to the e-

commerce and ERP realm (Heydenrych, 2007). The PRISM methodology can thus be described as a pragmatic approach to ensure success during the implementation of e-commerce applications in the ERP realm by placing the emphasis on human constructs rather than system constructs.

The biggest individual challenge is the frame of mind of implementation consultants holding onto the traditional approaches of implementation of e-commerce applications in the ERP environment. Emphasis must be placed on best business practices, as well as best fit concepts, to ensure that process definition is expedient allowing most time to be spend on data migration, testing and training. Further more, value engineering must be considered as part of the sales cycle to ensure return on investment and lowest total cost of ownership.

Implementation Technologies

It is evident from the results presented in this paper that the Prism Methodology can have a lasting impact on the implementation of e-commerce applications in the ERP environment through a creative approach allowing for a bigger focus on the human constructs rather than the system constructs. Another fundamental concept, which will allow for a new paradigm, is the concept of re-usability of business processes, functional and technical components. Pre-Project activities, as part of such a methodology will ensure that the organization is ready to execute such a project with absolute conviction, driving out all aspects of risk.

Sound data migration strategies, testing and training strategies, plans and tools as well as pre-defined content will ensure the success of such a methodology. A sound dynamic and iterative repository with all the major building blocks encapsulated will ensure that the model can be inverted to ensure that customer assimilation gets the required focus and emphasis.

Nowadays, in the emerging ERP research area, the definition and measurement of ERP implementation success is a thorny issue. Markus and Tanis (2000) state that success means different things, depending on who defines it. Thus, for instance, project managers and implementation consultants often define success in terms of completing the project on time and within budget. But people whose job is to adopt ERP systems and use them to achieve business results tend to emphasize having a smooth transition to stable operations with the new system. This will allow them to achieve intended business improvements like inventory reductions, and gaining improved decision support capabilities (Markus & Tanis, 2000, p2). This relative point of view for success can also be applied to failure, and people will also qualify an implementation as a failure according to their goals.

Considering the radical business changes required for the implementation of ERP systems, combined with the inherent complexity of these packages, it is not surprising that making the transition to ERP is neither easy nor quick. ERP is indeed often identified with out-of-control budgets and questionable returns (Schneider, 1999). Appleton (1997) claims that about half of ERP projects fail to achieve hoped-for benefits because managers significantly underestimate the efforts involved in managing change.

Hammer and Champy (1993) define a business process as “a collection of activities that take one or more kinds of input and create an output that is of value to the customer.” An example is the business process of mortgage processing. This process involves several activities, one of which is ‘risk evaluation of client.’ This activity can be decomposed to the following tasks: (i) perform credit check and (ii) perform net worth calculation. The input is mortgage application sent in by the branch, and the output is the mortgage product. For an e-process, the breakdown into activities and tasks is not as important as the operational information used by workers to execute tasks. Rather than as a rigid collection of activities, an e-process can be considered a more flexible collection of business rules used by workers to organize and execute activities. For an e-process, many stakeholders provide inputs. In the case of mortgage processing, the initiating input is the

mortgage application. But this can arrive from a variety of sources including on-line customers, mortgage brokers, and the branches. The arrival of this input into the mortgage processing process in itself could be governed by other processes. The output is also no longer simply the mortgage product. An e-process can present the mortgage product but also additional complementary products such as insurance and home equity loans (possibly governed by other processes). The output to the customer then becomes a unique value proposition rather than merely the mortgage product. Activities such as risk evaluation could be codified and performed by systems with only exceptions being directed to a human. Based on the analysis, the following definition of an e-process is presented to guide the translation of business process re-engineering (BPR) best practices.

An e-process is a collection of business rules that can be applied, using the Internet and World Wide Web (WWW), on any recurrent request (input) that then coordinates web of interactions (processes/additional input) across the value network extending from customer, firm and suppliers (stakeholders) to deliver unique value (output) to these stakeholders.

Successful implementation technologies depend on a host of factors, for example:

- Identification of a project coordinator
- The need for a project sponsor
- Quality project management
- A solid business plan and clear vision
- Sustained management support
- Effective organisational change management
- Strong ERP teamwork and composition
- Comprehensive business process reengineering, etc.

Integration of e-commerce and financial integration solutions should add value to organizations' operations and provide the company with well-defined advantages over non-integrated solutions. System integration should for e.g. cut various costs in the organization, add value to the operations of an enterprise by supply and value chain optimisation and automation, and add value to the customers and business partners of the company. Integration costs are said to consume an average of 24 percent of yearly IT budgets (Gartner, 2000) and Forrester Research estimates that up to 35 percent of development time is devoted to creating interfaces and points of integration for applications and data sources. According to InfoWorld's 2002 Application Integration Survey of IT leaders, EAI (enterprise application integration) is still "a tough and expensive nut to crack despite advances in technology". Although the marketplace for EAI tools and services is mature, no one vendor or consultancy stood out in the survey. IT managers of today still have to solve integration problems by using multiple vendors' products and services.

When evaluating whether the integration of e-commerce and financial information systems is successfully implemented, the following factors should be taken into account. These factors are quite high level, but they demonstrate all aspects of the integration, and the main drivers, why organizations today are so enthusiastically integrating their existing systems and implementing new and better ones in place. From this list managers should easily be able to identify, if one or more of these factors are not in their place in the organization and immediate action can be taken to correct the matter. In specialized and complicated organizations some factors may be more critical than others. This list is not in any special order as all of these are equally important in the average organization.

Financial information systems can be seen as the back-bone to any logistically driven supply chain related processes. Policies or procedures and any e-commerce based process definition therefore require detailed integration to financial systems. The following list contains some of the critical factors identifying the successful integration of e-commerce and financial information systems in an ERP system:

- Connected Corporation
- Reengineered Business Processes
- Optimised Processes
- Automated Processes
- Added Value to the Organization
- Added Value to the Customers
- Cut Overhead Costs
- Efficiently Utilized Middleware
- Integrated Services, etc.

Changes that Should be Implemented within a New Methodology

From a recent literature study as reported by Heydenrych (2007), commercial ERP applications such as ASAP, ARIS, Peoplesoft, etc. were compared. It became evident that there are many gaps in the methodologies and that a new methodology can bring much value to the implementation of ERP and e-commerce applications through a systemic approach whereby the templates and tools will be designed with an understanding that everything is interdependent.

The following paragraphs emphasize changes what should be implemented within a new methodology:

- Most methodologies assume that the business design within the organization will be frozen for the duration of the project. Furthermore companies are seeking competitive advantage and therefore the methodologies investigated failed to recognize that companies need to design superior and very specific processes to differentiate themselves from the competition. The methodologies that were studied do not encapsulate a sound pre-project delivery phase to establish sound deployment models and implementation strategies.
- Most methodologies do not have a pre-project step to ensure the readiness of the organization through process definition, data cleansing and organizational structure determination as well as team identification and ways to backfill for core project team members. The methodologies investigated do not embrace the preparation of consulting teams for specific projects or customers. None of the methodologies that were investigated recognized the importance of the preparation of the customer team.
- Very few methodologies embrace building block concepts whereby pieces of functionality is designed once, packaged and delivered when required as part of a bigger holistic process. In most of the methodologies integrated testing is discussed in detail but never well executed due to a lack of integrated test scripts with customer specific master data and transaction data.
- In most of the methodologies, communication is not being addressed adequately. No messages are defined and no determination is made on what communication media and

frequencies of messages to use. Change Management is not well addressed at all and very little effort is made to understand the impact of changes in process, procedures and roles.

- Most methodologies embrace the concepts of training strategy, training planning, training scheduling and training curriculum but in most cases this is not executed well at all resulting in end users not being ready to do their jobs within the ERP and e-commerce applications.
- Most of the methodologies investigated spend very little time in the definition of required roles and security. Often they have none or very little tools to assist in this aspect as well.
- Most methodologies do not embrace sound post project support and on-going continuous improvement. A debrief of the project should be done by consultants and business owners so that methodologies can be adjusted and improved based on issues experienced during the project. Time must be made on projects to record all documentation and therefore documentation as a task must be incorporated into the daily schedule of a project in the ERP or e-commerce world.
- The methodologies studied do not ensure user friendliness through design and screen selection.
- Strategy determination is fundamentally important during the implementation of ERP and e-commerce applications.
- Quality reviews must be part of a systemic methodology to ensure progress and measurements of milestones

A questionnaire was hence developed that embraced all the issues and gaps discovered in current commercial applications to address problems during the implementation of ERP or e-commerce applications. Questions were included in the questionnaire to ensure clarity around specific aspects where improvements will be very beneficial to the business and systems community at large via a systemic approach. A large number of questionnaires were allocated to business associates and change managers in the e-commerce and ERP community in the USA and Europe. Three hundred and fifty questionnaires were distributed of which one hundred and eighty two were received back within the required time period indicating an initial success rate of 52.0%. Unfortunately, some questionnaires were incorrectly completed resulting in one hundred and forty seven of the returned questionnaires being available for statistical analysis and interpretation (42%). (The results and analysis thereof are bulky documents and will only be presented in summarized form for the purposes of this research paper. Any queries on the research model can be directed to the authors.).

It is very important that the business will drive change and not the IT department. To ensure that this is accomplished, business process owners and subject matter experts must be selected from the business environment with support from the IT environment. Team selection must therefore be incorporated into a systemic methodology that will ensure the correct grouping of business related team members, consultants and IT staff to form teams that can drive change effectively and make quick decisions (Zairi & Sinclair, 1995).

In the opinion of the authors, this should also include an interview process before the project commences that will ensure compatibility between customer and consultant team members.

Main Features of the Prism Methodology

It is absolutely imperative that a new methodology will have a simplistic yet repeatable model that will bring huge benefits to consulting and customer teams and will be dynamic in nature al-

lowing for an integrated approach and easy updating of the components when required. This new methodology will be called the Prism methodology (Pragmatic and Repeatable Implementation and System Methodology). PRISM can be contrasted to the following products or methodologies such as the ASAP methodology, *The Total Solution*, *Fast Track Methodology* and *ARIS Methodology* (Heydenrych, 2007).

The pictorial representation in Figure 1 depicts the potential new methodology that is proposed and the components associated with such a methodology (Heydenrych, 2007).

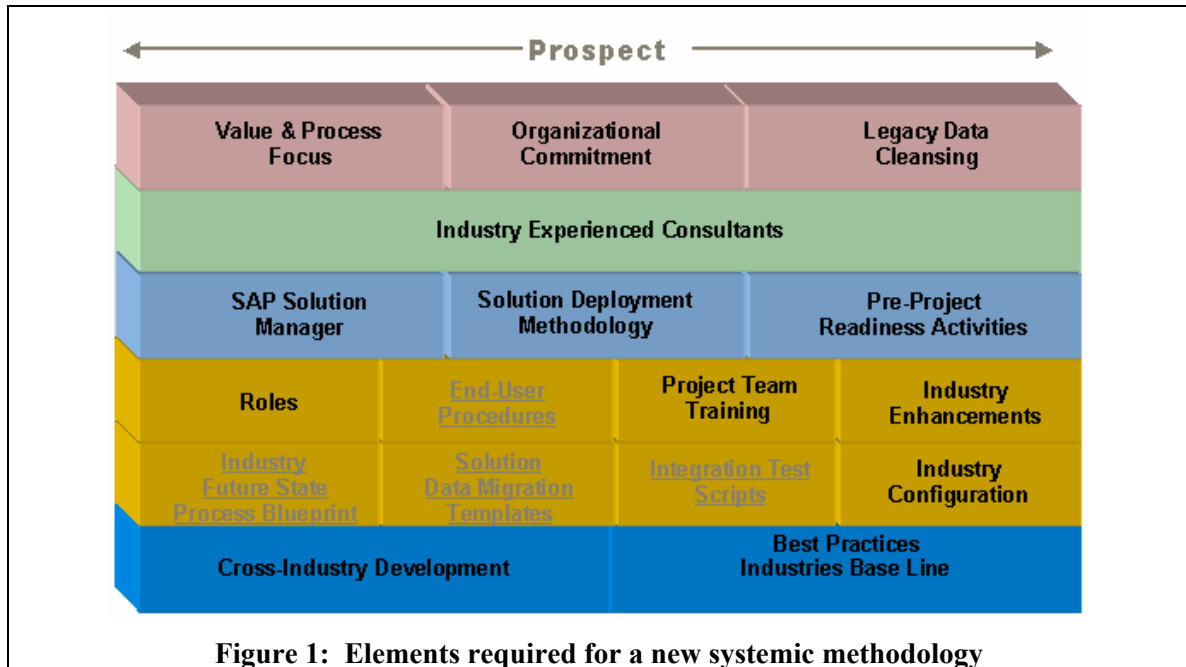


Figure 1: Elements required for a new systemic methodology

It is evident from the empirical study that the new proposed Prism methodology can bring much value and success within the e-commerce realm. This methodology place a bigger emphasis on the human constructs rather than the systems constructs by inverting traditional models to concentrate on data conversion, testing, training, organizational readiness and change management. Process definition must be encapsulated as far as possible within best business practice concepts to ensure such an inversion to be successful. Most scenarios must therefore be pre-defined to ensure a focus on customer assimilation (Heydenrych, 2007). It is therefore clear that the concepts encapsulated within the PRISM methodology can also be used for the implementation of customer relationship management projects within the ERP world.

The main elements of the PRISM methodology include:

- Business Blueprint documentation and templates based on industry specific best business practices
- Business Process Procedures
- Process Flow Diagrams representing business processes
- Data Migration spreadsheets and tools
- Integrated process scripts, scenario's and logs
- Role definitions by industry and process
- End User Procedures and Training Materials

- Change Management Tools
- Risk assessment tools
- Communication templates and tools
- Process Impact analysis tools, etc.

The Potential Benefits of a New Methodology

Multiple case studies are available that show that when the emphasis is placed on human elements, rather than system elements, customer assimilation is achieved much quicker and the chance of success dramatically increases. Research by AMR shows that only 6% of e-commerce application implementations in the ERP world is spent on configuration and as much as 66 % on change management (AMR Research, 2000). Although it is out of the scope of this paper to go into precise detail of the elements in Figure 1, it can be mentioned that multiple industries, functional applications and processes have been considered by the respondents to ensure that a systemic approach and new methodology will be universally applicable.

As an example some observations from the analysis of the survey that point to areas where a new technology can be beneficial are listed:

- The average score on the question on templates and tools shows that most of the methodologies that were considered lack in templates and tools to assist consultants and business process owners to implement systems successfully in the e-commerce and ERP environment
- Questions regarding pre-sales activities show that hand-over processes from pre-sales to implementation must be improved and that the tools used in the process must be reconsidered.
- It is also very evident that the results of the questionnaire indicate that serious consideration must be given to specific pre-project activities and that such activities must become part of systemic approach and new methodology for the implementation of e-commerce systems in the ERP environment.
- The results further indicate that customers in general are moderately prepared for the implementation of an e-commerce or ERP system. However it is evident that change management activities are predominantly lacking resulting in issues later on in the project. Backfilling and readiness assessment show as weaknesses in most of the replies in the questionnaire.
- Questions on the consulting team preparation and readiness show that the consulting team is under most circumstances not well prepared. Readiness was lacking in the areas of project specific preparation, visibility to templates / tools and addressing industry specific issues.
- The concept of pre-delivered industry solutions did not receive good scores. It is clear that the concepts of best business practices have not been translated well into templates, tools, guides, white papers, blueprints documents etc. as might have been expected. It appears that redesigning the wheel is still the strategy followed in most cases.
- The results of Business Process Definition show that in most cases To-Be business processes are defined from scratch rather than doing fit gap analysis of specific requirements to pre-configured systems. Business process definition, business process re-engineering

and the adjustment of strategies, policies and procedures are some examples to make these pre-delivered processes work.

- The questions on training show that training strategies are seldom prepared in advance of a project because the creation of the training strategy is not part of any of the considered methodologies. Further questions show that there is a much higher propensity to devise training strategies during the project. Unfortunately, a follow-up question on knowledge transfer shows that knowledge transfer and determination of customer assimilation is not measured as part of the deliverables of a project leaving a big question mark whether knowledge transfer has been achieved.

The new proposed Prism methodology can bring much value and success within the e-commerce realm by addressing the problem areas listed above. This methodology place a bigger emphasis on the human constructs rather than the systems constructs by inverting traditional models to concentrate on data conversion, testing, training, organizational readiness and change management. Process definition must be encapsulated as far as possible within best business practice concepts to ensure such an inversion to be successful and most scenarios must be pre-defined to ensure a focus on customer assimilation.

Meeting the Needs of South African Businesses

Research undertaken in 2001 by a group of three post graduate students at the Department of Information Systems at the University of Cape Town indicated that the academic material covered by Information Systems departments at universities in South Africa does not meet the expectations of industry to a large extent (Cloete, 2002).

Aspects such as taxation, security, privacy, content development and regulation, electronic payment systems and standards, and interoperability have made it necessary for the South African government to develop a green paper on e-commerce (Green Paper on Electronic Commerce for South Africa, 2000). In this document, the government has attempted to address issues related to e-commerce with particular significance to South Africa. The paper highlights the fact that the rate of adoption of e-commerce by South African citizens is relatively high when compared with other countries in Africa and most other developing countries.

Based on the findings of Benjamin, Meara, and Suleman (2001) it was be concluded that South African Tertiary Providers (universities, technikons, etc) are not meeting the general requirements of South African businesses in training students in new e-technologies. The reasons for this are:

- e-Commerce professionals and e-commerce courses assign differing relative importance to theoretical skills, although the principles of e-commerce marketing, e-commerce strategy and e-commerce legal/ethical issues appear to be rated at similar levels of importance.
- Large disparities are evident with regard to e-commerce development methodologies, network topologies, hardware and security issues. This will obviously require attention from the stakeholder groups.

While differences were observed between the level of importance assigned to practical components of an e-commerce course as designed by the practitioner group and academics, it was concluded that universities are emphasising practical and applied experiences in a fashion which correlates closely to business requirements. It was encouraging to note that both groups appear to be in agreement on the technical architecture and software platforms used in the practical components of e-business courses. In addition, there were consensus with regard to the learning value of group exercises and projects that promote teamwork and collaboration.

In the light of the research of Benjamin et al. (2001) and the course evaluation of the first group of students to take the e-commerce course at the Department of Information Systems at the University of Cape Town, the following was observed:

- There was a clear need for greater collaboration and communication between designers of e-commerce curricula, and e-commerce practitioners. Both groups should engage actively with one another to ensure the continued development of e-commerce education in South Africa.
- The emphasis which IS departments are placing on teamwork and project based collaboration is aligned with South African business requirements and should be maintained.
- Due to the velocity of change in e-commerce applications, this research method should be conducted periodically to deal with the rapidly changing market circumstances.

It is important to note that this study was conducted with a South African perspective in mind. Similar research is now being conducted in other sub-Saharan countries in collaborating with the University of Cape Town.

The inclusion of theory on successful e-transformation in e-business syllabi, as described in this paper, is essential considering the number of companies globally that are still not involved in fully fledged e-commerce.

Conclusion

This paper highlights concepts of e-transformation that is often taken for granted and can result in failure of ERP and e-commerce ventures. The Prism Methodology is an example of a new technology that could be included in e-business tuition to emphasize people aspects in re-engineering.

Training is considered as an absolute necessity in a new Prism Methodology, and every opportunity to address training aspects must be utilised. It is a fact that customer assimilation is the biggest individual issue on any accelerated project and this must be addressed in a pragmatic manner to ensure success. Training must start during pre-project activities and include the following during the project lifetime:

- Boot camp Training
- Configuration Training
- Train the Trainer
- Integration Testing

Follow-up research will be required to establish how efficient and successful the Prism methodology may be in a multitude of situations dependent upon culture of the customer organization, readiness of the consulting organization, scope, change management issues, training programs, testing plans, data migration tools as well as program and project management tools and templates.

Futuristic research to be considered must include but is not limited to:

- Applicability of steps within the Prism methodology
- Efficiency of the templates and tools utilized within the Prism methodology
- Adjustments required to the Prism methodology to improve success rates
- Does the Prism methodology successfully address the main issues identified

- Does the Prism methodology address the human constructs sufficiently

Other students and interested parties are invited to participate in such futuristic research in an attempt to continuously improve the Prism methodology. The Prism methodology will have to be tested and tried to establish applicability and value to the systems community at large within the context of e-commerce applications and ERP constructs. New implementation models, inclusive of off-shoring for configuration must be researched to determine viability and how consulting organizations must adjust to accomplish the task of on-site testing and training to ensure customer assimilation.

Our experience in offering an e-commerce module in the Department of Information Systems at UCT was received favourable by the large group of students who completed the course. This fact is reflected in the yearly course evaluations, but the most promising feedback is definitely students coming back with URL's of real sites they have been developing in the few months after the course. Students are also involved in e-commerce by joining e-business ventures or setting up their own start-up companies; locally or abroad. Incorporating new technology and theory on new methodologies on a regular basis can only strengthen a robust and crucial course in the IS core syllabus.

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Biographies



As Director of Industry Solutions at itelligence, **Johann Heydenrych** is responsible for the development and accreditation of vertical industry solutions. He specializes in providing organizations with enterprise resource planning and e-business solutions.

Mr. Heydenrych has over 20 years of business technology experience, including almost ten years in senior management positions. Prior to his position as Director of Industry Solutions and Industry Solution Manager, Heydenrych served as Project Manager and Business System Architect for itelligence from 2000 until January 2004. At itelligence, Mr. Heydenrych implemented SAP solutions for companies such as Gold Medal Bakery, Caterpillar, East Balt Bakery, Johnsonville, Radisys, DeBeers Diamond Mines, South African Breweries, Porky Products, Ubiquity and Bradley Corporation

Prior to joining itelligence, Mr. Heydenrych was the Project Manager and Senior SAP Consultant for Hatch Incorporated, where he was involved in the configuration and implementation of Hatch's SAP system. He also held a senior position at Saskor Corporation, where he was responsible for the implementation of all systems and projects for operational activities throughout the company's 175 sites.

Heydenrych received a Bachelor of Commerce degree from the University of South Africa and an M.B.A. from the University of Potchefstroom (South Africa). He is currently pursuing a Ph.D. in the subject of Supply Chain in the ERP Environment, spanning the creation of a new methodology.



Dr. **Cloete** has been involved in tertiary education for most of the past 25 years. He lectured at a number of South African universities and technikons, whilst conducting research in a number of different computer fields, ranging from Parallel Processing to Image Processing. Currently he is mainly involved with Electronic Commerce lecturing and research and has published numerous articles on South African progress in this field.

Dr Cloete is also involved in the private sector as a consultant and mentor and is associated to numerous professional institutions. He holds degrees in mathematics, applied mathematics, computer science and did his doctorate in Image Processing.