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DEVELOPMENT OF STRATEGY PULL TYPE KM MODEL: IMPLICATIONS FOR ACHIEVING QUALITY OUTCOMES IN ENGINEERING EDUCATION

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Abstract

Engineering is a creative field. It demands a group of abilities including, analysis, synthesis, designing, evaluation, experimentation, and so on, along with managerial and leadership qualities. In this new era of Information Revolution, when organisations are transforming themselves into Learning Organisations with effective Knowledge Management (KM) techniques, there is also a need to transform the engineering education system (which supplies human resources into those organisations) into a Learning Institution through the implementation of the appropriate KM model.

Focus group sample method of research is adopted in this paper. The study is qualitative in nature and is based on the inputs given by the teaching faculty from about 20 engineering institutions. Response to the qualitative questions is the main source of data. Validity study of the research is also presented in the paper.

This paper proposes a strategy pull type KM model. The building of the knowledge flow pattern in engineering education is carried out. Knowledge maps are developed to establish the relation between the engineering attributes and the courses studied. The conceptual integrated framework for KM is also developed. The paper gives a stage-wise implementation strategy for the KM system, and also, enlists the implications for quality outcomes. The paper aims at a full-fledged KM system in engineering education, which would facilitate producing of quality conscious and customer-focussed engineers, who can respond to the dynamic, discontinuous and radical pace of change in the techno-societal front.

Keywords: Knowledge Management - Engineering Education - Strategy Pull Model

Introduction

Globalization, liberalisation, and privatisation have made competition inevitable and customer driven markets have made quality, reliability and cost effectiveness the survival tools for both production and service sectors. To cope with this radical change, the organisations of today have incorporated 'systemic thinking' and most of the top-notch organisations have transformed themselves into 'learning organisations'. KM has emerged out as an effective tool in this framework.

The global demand for quality conscious knowledge workers has exerted a tremendous pressure on higher education in general, and engineering education in particular. Computers have already invaded almost all walks of life and information handling has become one of the important tasks to be accomplished in any business, may it be hospitality, tourism, health care, or manufacturing. Hence, the engineers of the future will have to be more adaptable and smart enough to anticipate the challenges of the future and seek creative solutions both to technological and societal problems. Information proliferation has, no doubt, helped in building strong database, but making the right kind of information available at the right time has become a challenge and that is where KM finds its use, particularly in knowledge intensive sectors. Therefore, in this context, a systematic study of KM and its implementation strategy in engineering institutes would contribute highly not only to the improvement in the effectiveness of knowledge dissemination but also in enhancing innovative and creative spirits in the learners.

Literature Review

An engineering education institute is a knowledge-intensive service sector, the important function of which is to pump the future engineers with knowledge, skill, attitude, values and responsiveness to societal needs. Across sectors, knowledge intensive organisations increasingly face similar conditions with a strong connection between the individual organisation's ability to mobilise, apply and disseminate knowledge resources on the one hand, and maintaining competitiveness on the other [1]. The academic department or institute is among those (often public) environments facing rapid change as a result of new demands for commercialisation of knowledge, a need for a more efficient utilisation of human resources due to cut-backs in basic funding, as well as introduction of new accountability from the government [2]. These changes demand new ways of working, for instance, in the prevalence of industry-institute co-operation, increased dependence on external funding, improved team work, inter-team learning, multi-disciplinary and even trans-disciplinary approach.

Zuckerman & Buell [3], define KM as the strategic application of collective company knowledge and know-how to build profits and market share. Knowledge assets viz., ideas, concepts, and know-how are created through computerized collection, storage, sharing and linking of corporate knowledge pools. Advanced technologies make it possible to mine the corporate mind.

Turban & Aronson [4], describe KM as a process that helps organisations identify, select, organize, disseminate, and transfer important information and expertise that are part of the organisational memory, that typically resides within the organisation in an unstructured manner.

There are several managerial functions associated with the label of KM such as identifying and valuing knowledge assets, leveraging these assets through knowledge sharing and creating new knowledge [5]. Many of the processes for measuring intangible assets and managing knowledge originally developed for private firms, have been found to be useful for supporting the university [6]. This includes:

- Offering competent and effective services.
- Preparing for, building and leveraging public and private intellectual capital, and
- Helping the public understanding of the needs and direction of public activities, programmes, and projects.

The main purpose of a KM system is to promote ‘innovation management’. As Castells [7] states, “What characterises the current technological revolution is not the centrality of knowledge and information, but the application of such knowledge and information to knowledge generation and information processing/communication devices, in a cumulative feedback loop between innovation and the uses of innovation”. Hence the purpose of introducing the KM model in any set up should be to promote innovative and creative abilities of human resources.

Two basic paradigms exist in knowledge management i.e. ‘information technology’ influence and ‘organisational learning’ influence [8]. In an engineering education setting, both have significant influence. However, organisational learning needs greater attention as it involves both the social and technological systems. It strengthens the linkages between KM, human resources management (HRM) and strategic development (SD). It also has a greater focus on people, the engineering education system being a service-oriented sector; this is very much required for its growth. In order to accomplish the long-term vision of the education system, the learning influence thus contributes to a greater extent.

Objectives

The objective of this paper is to provide a framework for the KM system for engineering institutions, which would:

1. create knowledge repositories,
2. improve knowledge access,
3. enhance knowledge sharing,
4. manage knowledge as an asset, and
5. develop a learning culture at all levels.

Methodology

Focus Group Sample

The conceptual model development was basically in consultation with a focus group, which consisted of 37 teaching faculty members in engineering institutions spread all over India. It included 6 professors, 11 assistant professors and 20 lecturers spread over the age group of 25 to 58. The group was meeting on a 3-day national seminar (27 -30 Dec, 2003) of technical education. Stratified purposeful sampling was employed, ensuring that the group consisted of individuals representative of a number of disciplinary affiliations and work profiles. Out of the 37 respondents 32 were from private engineering institutes, 3 from government institutes and 2 from deemed universities.

Procedure and Analysis

The data collection was very informal through information interviews and deliberations. The purpose of the interview was made clear to them in a formal way. The contributing factors for the various components of KM model were asked and suggestions were recorded. Whenever the basic concepts of KM were asked for, it was made clear to the respondents. Questions were very direct e.g., 'Which could be the sources for knowledge creation in an engineering institute?' The answers were recorded and used in the formation of the KM framework at a later stage.

Validity of the study

The focus group selection represents a fairly broad selection of disciplines and types of institutes/departments. The age distribution is fairly even, and the types of positions involved are spread over a number of academic levels/tasks. The spread of disciplinary orientation and task orientation ensures that a diversity of variations have had the chance to occur, yet the common academic background facilities and sharing of common experience controls the same. One concern may be that the sample does not include any cross-national comparisons, but rather have national context, i.e. India. But this may be compensated by the fact that several of the teaching faculty consulted, have had an international teaching exposure, and some of the institutes are *de facto* international contexts in their own right.

Finally, since the participants volunteered to take part in this study they most likely represented a group of individuals who nurture an interest in academic management. However, the purpose of this research was not to discuss how effective a component would be in KM, but to generate possibilities. In this regard, the group represented a theoretical sample of individuals, i.e. of persons who had something to say about the topic at hand.

Conceptual Integrated Framework for KM

The Conceptual Integrated Framework for KM is given in Fig. 1. It shows the integration of Strategy, Technology and Institutional Knowledge. It shows how institutional knowledge is formed by the interaction between people, technologies and techniques.

The strategic goals of the institute play a key role in the development of the KM system. The triple mission of the institution viz. Research, Teaching-Learning and Service to the society, is driven by both the external and internal drivers. The key management imperatives would be Innovation and Creativity. Technology plays a major role in data - storage, up-gradation, transfer and presentation. Appropriate technologies have to be selected for performing the required functions. Appendix 3 lists the various KM technologies available for performing the various sub-processes of KM as given by Al-Ghassani et al [9].

Application of the appropriate techniques also plays a pivotal role in efficiently gathering, evaluating, structuring, and distributing the intellectual capital. Some of the business management techniques such as SWOT analysis, Balanced Score Cards [10], Process Flow and Object State Description Capture Method [11], Role Activity Diagrams, [12], Knowledge-based Applications [13] etc. may also be used in an institutional set-up, based on their appropriateness.

Knowledge Flow Model Development

Individual knowledge is necessary for developing organisational knowledge base; however, organisational knowledge is not a simple sum of the individual knowledge [14]. Organisational knowledge is formed through unique patterns of interaction between technologies, techniques and people. Again, knowledge may be foreground based or background based. Foreground knowledge is much easier to capture, codify, and imitate, while background knowledge is tacit, which makes it difficult to replicate and imitate. However, the success of an organisation need not necessarily be a function of background knowledge [15]. Rather, it is the symbiotic relationship between the foreground and background knowledge that forms the core-competencies of the organisation and offers a sustainable advantage to the company [16]. Hence, it is clear from these arguments that while developing a KM model, the symbiotic relationships between the foreground and background knowledge has to be given importance.

The development of a KM system consists of identification of the raw facts, which form the 'data', followed by the processing of the data and organising it into 'information' and forming a database of useful information, which is perceived as 'knowledge'.

The KM in the engineering institutional context is defined in the following terms:

"KM in an engineering institution provides a knowledge base, which strategically enables to record sustainable development in the areas of teaching, research, and service to the society, thus, enabling the institution to fully develop and utilise its core competencies through the integration of technologies, technique and people."

Institutional Knowledge

Institutional knowledge is formed by the interaction between people, technologies and technique. It is unique to a given institution. This is because the interaction between these components is based on the type of institute's physical and human resources, and others cannot easily imitate it. Moreover, it is also a function of the core-competence, meta-competence and work-competence of the faculty. So there must be a systematic method of developing an institutional knowledge, so that it could be stored as the intellectual property of the institution for the future generations.

Knowledge Creation

Marakas [17] defines knowledge creation as the ability to develop novel and useful ideas and solutions. This is the starting phase of the Knowledge Flow Pattern in Engineering Education as shown in Fig. 2. The effectiveness of the rest of the phases is solely based on the ability to create knowledge. The strategy driven pull model [18] gives insight into strategic planning and then driving the KM system to suit to the corporate vision. This could prove to be very effective even in the institutional setting. The institution should clearly define its short-term and long-term goals and then decide the type of knowledge it would like to create in order to accomplish the stated goal. Strengthening of the research capabilities, scanning the external environments and predicting the future threats and possible ways to cope with the changing scenario would be a very useful source of knowledge creation. Consultancies offered to the industries, experience of the faculty in solving specific cases, publications in various fields of interest, results of experimentation, text books with ample case studies, industrial interaction, study of the societal needs, extensive research in emerging areas, IT/internet/computer based training (CBT) and all other electronic media would facilitate the process of knowledge creation.

Knowledge Validation

This refers to the extent to which a firm can reflect on knowledge and evaluate its effectiveness for the existing organisational environment [5]. Validation of knowledge in engineering education becomes very important, because with time, technology becomes obsolete and there must be a mechanism to check its validity from time to time. Validation is to be done by the constant interaction between technologies, techniques and people. The HRD department must keep a track of the faculty who have undergone training in certain specialized areas and entrust them with the task of validating the knowledge. At the same time the faculty needs up-gradation programmes at regular intervals so as to keep abreast of the changing techniques and technology. Knowledge validation may be done through testing obsolescence, testing methods/techniques, refining, benchmarking, usefulness analysis, testing practicability etc.

Knowledge Storage and Presentation

Knowledge presentation refers to the ways in which knowledge is displayed to the institutional members. It is very important to present the knowledge to the faulty in a clear and simple manner. The storage and presentation may be in the form of hard copy, video/audio, books, soft copy, optical media, internet/intranet and many other forms. Standardisation is a very important part of knowledge storage and distribution. A uniform format may be used to store and present the data throughout the institution to promote similar codification, standards and programming schemes. Predefined templates and schema to present the knowledge would be very handy.

Knowledge Distribution

Knowledge needs to be distributed among the entire faculty at the same rate at which it is created, in the shortest possible time, in order to prevent obsolescence. The interaction between people, techniques and technology plays a very important role in the process of knowledge distribution. The decentralized form of organisational structure, empowerment, informal communication, participative management, open door policy style etc. promote faster distribution of knowledge. E-mail, internet/intranet, discussion forums, personal calls, notice/bulletin boards, newsletters, meetings, circulars/memos etc. may be effective media for the distribution of knowledge.

Knowledge Application

This forms the final phase of KM, the very purpose of which is to apply the available knowledge to the products, processes, systems and services. The whole idea is to have the right kind of knowledge available at the right time in the right place. As innovation and creativity play a vital role in the success of any organisation today, immediate access to knowledge plays a critical role. For example, in an institutional set-up if new educational technology is available in a particular area, it should find a place for application at the earliest possible time, so that the student community gets maximum benefit out of it. To cite another example, if a faculty member has updated himself in a technique such as TRIZ(Theory of

Inventive Problem Solving), the knowledge should be distributed across the teaching and student community, so that they can apply the same in the shortest possible time.

Knowledge creation may change from institute to institute based on the strategic plan but the flow will be common to all the institutes. The design of this flow is based on the 'strategy pull', rather than 'technology push' type of the KM approach. This is because engineering institutions of today are open to the global market and pass through various accreditations criteria, which vary from country to country. However, all the top quality institutions round the globe have clear vision and mission statements and are also strategy driven. They have clear definitions for their corporate policy, quality policy and have identified their core competencies. Many of them have already started innovation centres in collaboration with industries and research culture is imbibed in the system. 'Culture building' will become an important part of the growth strategy of the institutes, as response to change would be one of the critical factors contributing to success. Hence, the directing of the individual knowledge for the institutional purpose and a knowledge sharing culture will be the necessity of the future years.

The process of knowledge creation, validation, storage and presentation, distribution and application flow in the same sequence as listed. The various influencing factors shown in Fig. 2 are collected through the procedure mentioned in the research methodology.

Implementation of the Institutional KM system

1. *Strategy phase – where the KM strategy is aligned with institutional strategy*

During the strategy phase a thorough study of the strategies, missions, goals and objectives of the institution is undertaken. This should consider both the short and long term goals of the institution. Provisions must be made for the incorporation of diversification plans. Once the strategy of the institution has been studied, to suit this requirement the KM strategy will have to be developed. This forms the basis of the strategy pull type KM model implementation that is illustrated in Fig. 3 [19]. It can be observed that the dynamically updated outcomes pull the human and machine intelligence in such a system. Information & communication technology (ICT) are only used as the tools to accomplish the organisational strategies. The greatest advantage of this model is that it accommodates the radical and discontinuous changes in the customer requirements.

2. *Knowledge Architecture*

Knowledge Architecture includes decisions on developing specific goals for the KM programme. It is basically developing the architecture to support the strategic goals set in the previous phase. Knowledge mapping constitutes the major part of building the knowledge architecture. Knowledge maps are the nerve centres of a good KM system and they mainly act as the intellectual infrastructure. There are different types of KM maps, which are context based. The knowledge maps provide information such as where the knowledge is located, who needs that knowledge, how to classify knowledge and how to apply the same. For example, if a student wishes to know about the various courses available in a branch, and the interlinked graduate attributes, a knowledge map would provide the required information. The mapping of curriculum in mechanical engineering for the key attributes prescribed by the ABET criterion [20], showing the interconnectivity of the courses is given in Fig. 4. The corresponding graduate attributes have been listed in Appendix 1 and the codes used are listed for a sample bachelor's course in mechanical engineering in Appendix 2. Such knowledge maps will have to be generated for the entire education system, for the three sections (teaching, research and service) of the institute discussed in the integrated KM framework, and made available to the users.

3. Systems and Technology

This involves the decisions about setting up implementation structures, creating formal and informal systems to manage (create, validate, store, present and apply) knowledge objects, augmenting the technology infrastructure to facilitate systems and manage its contents.

Depending on the form of knowledge object (tacit or explicit) and the type and of location of users, appropriate systems need to be set up. Systems could be either formal or informal. Formal systems include working in cross-functional work teams, creating interdependence across multi-disciplinary branches, on-the-job training etc. Informal systems could be induction, mentoring, experience sharing etc.

The technology mainly consists of IT infrastructure. Some very common applications are email, internet, intranet, bulletin boards etc. Emphasis should be laid on the display of FAQs, best practice sharing, problem solving, etc. An extensive list of KM technologies classified by KM sub-processes is given in Appendix 3.

4. People Issues

After deciding on the KM architecture and having set up the systems and technologies, the final phase would be to make people participate in the KM programme and reap the benefit. This stage is focussed on people in order to create awareness about the KM system, motivate them to participate (access, review, contribute or apply knowledge objects) and by and large create a culture of knowledge sharing. A Chief Knowledge Officer (CKO) may be appointed whose role would be to educate people on KM through different means such as generating email campaign, producing newsletters and pamphlets, holding events and summits to demonstrate the distinct advantages of KM, and coordinate the overall functioning of KM system.

Factors Influencing the Institutional KM System

Types of Knowledge in Engineering Institutes

Polyani [21] was the first to conceptualise and distinguish between an organisation's *Tacit Knowledge* and *Explicit Knowledge.* Tacit knowledge is usually in the domain of subjective, cognitive and experiential learning (e.g., a certain skill), whereas, explicit knowledge deals more with objective, rational and technical knowledge (e.g., software development). Both of these knowledge types are present in an engineering institution. Whereas it is easy to store and distribute explicit knowledge, as it does not require interpersonal interaction, it is difficult to store and distribute tacit knowledge, as it is either embedded in the brain of an individual or a group of individuals.

Hossaple & Winston [22] define six types of knowledge, management application can contain, and incidentally all of these exist in an engineering institution too. This includes, descriptive, procedural, reasoning, linguistic, presentation and assimilative knowledge.

Descriptive Knowledge is information about the past, present and the future or hypothetical states of relevance concerned with *knowing what* e.g. the definitions, statements, hypotheses etc. used in engineering

Procedural Knowledge is concerned with *knowing how* and specific step-by-step procedures of how tasks are accomplished e.g. how to conduct a given experiment, how to do testing of concrete etc.

Reasoning Knowledge is concerned with *knowing why*, evaluating conclusions that are valid for a set of circumstances e.g. proving a theorem with a given set of assumptions.

Presentation Knowledge facilitates communication e.g. using computers in making effective presentations.

Linguistic Knowledge interprets communication once it is delivered e.g. comprehending Einstein's Theory of relativity once the mathematical proof is given.

Assimilative Knowledge helps to maintain the knowledge base by improving on the existing knowledge e.g. having studied Applied Mechanics, the ability of the student to use the fundamentals in solving the problems in Machine Design.

The first three kinds of knowledge mentioned above are the basic knowledge that the institution should possess for the general functioning and the latter provide communicating, understanding and learning of knowledge in order to use it. Different methods and means may have to be used in storing these different forms of knowledge.

Organisational Culture on Learning

The organisational culture, or in the present case, 'institutional culture' has a significant influence on its ability to learn, develop memory, and share knowledge. Culture refers to a pattern of shared basic assumptions [23]. Over a period of time, the employees of an institution learn what works and what doesn't. It then becomes a part of the institutional culture and the new employees learn the culture from their seniors and mentors. KM in particular depends on the institutional culture, as it heavily relies on individuals contributing knowledge to its repository [24].

Vaas [25], gives key reasons why people don't share knowledge:

- Willing to share, but no time.
- No skill in KM technique.
- Don't understand the benefits of KM.
- Lack of appropriate technology.
- No commitment from senior manager.
- No funding for KM.
- Culture does not encourage knowledge sharing.

The key to success is to create an institution with a culture of continuous change where employees, instead of being threatened by change, are encouraged by it and keep continuously feeding the new knowledge to the knowledge base. Hence, a strong cultural change is required and the management must take steps to ensure the same if a meaningful outcome is to be expected through KM.

Interaction between Technologies and Social Systems

The sole purpose of engineering is to make social life easier and enjoyable. Whether it is a process of building a bridge, automobile, electronic control system, communication system, automation or even a missile, it should be aimed at growth and progress of the society. This is possible only when there is a meaningful interaction between social systems and technologies. This is a very important factor to be considered while building a KM system.

To start with, the engineering educational institute should define the interaction between people, technology and techniques. There must be a provision for the society to access the KM system, define a problem that they face, and the solution sought for. The system should thus be made dynamic with new problems being fed into the system on a regular basis. The problem must then be categorized by a panel of engineers and the task force should work towards the solution. These may also be potential projects for the undergraduate or postgraduate students based on the level of difficulty.

Orr [26] discusses how two experienced technicians exchange quite different views regarding the malfunction of a photocopying machine. But if their views are stored centrally it may help the others a great deal as they don't have to re-invent the wheel. This approach could be of great help in an engineering institute, particularly when student engineers work on their final year projects.

An engineering institution is neither an exclusive artefact of a technological system nor a social system. It is a system of personal experience of the teaching faculty, social relations, technologies and techniques, which act in a combination to churn out the future engineers. Thus the KM system should facilitate the interaction of all its components for any meaningful outcome.

Implications for Achieving Quality Outcomes

Institutional KM system exists to strategically enable the institution to record sustainable development through the proper utilization and development of core-competencies in the organisation. The ultimate purpose is to develop the institution into a 'learning institution'. Only then, the proposed model can lead to quality outcomes.

Following are the step-wise implications:

1. Knowledge creation should be strongly based on strategic planning of the institution. For example, if the institution has a strategic plan to develop a full-fledged innovation centre, then, during the creation of the knowledge, the key factors and the tools & techniques, which would support the research activities, must be made available in the knowledge base to the best possible extent.
2. Provisions must be made to incorporate new knowledge, if any, from time to time. Technology is changing so fast that obsolescence handling will pose a greater challenge. Any outdated knowledge should immediately be removed from the database before it reaches the faculty.

3. All the new projects handled, testing performed, research breakthroughs, innovations, patents applied, best practices etc. should be made available to all the faculty members in the institution for observation.
4. The team performing the validation should be well in touch with the changing scenario in science and technology. It must consist of representatives from all the departments of the institute. Formation of inter-disciplinary teams would be highly beneficial.
5. Knowledge storage and presentation should be standardised across the institution. Presentation should be made as simple and clearly understandable as possible.
6. Knowledge distribution must be accurate and be made in real time. Distorted messages would result in ambiguity and hinder growth. Standard software and IT tools, which would not only provide uniformity but also enhance speed, must be used throughout the institution.
7. Knowledge application should not only be monitored but also supervised. When new methodologies are developed in teaching, they should be quickly spread across the departments for immediate use. The same is applicable for research breakthrough and other key issues.

The purpose of KM is not only to aim at reaching the strategic goals but also to enable the team to generate new goals in accordance with the advent of science and technological breakthroughs. What is needed is a cultural change in the environment. The environment of participation, coordination, and knowledge sharing should be built in the institute. Changing people's behaviour is one of the critical implementation problems in the KM according to 56% of executives in case of an organisational set-up [27]. This may be the case in engineering institutes too. So, the management must take initiatives to form KM teams and build a culture of knowledge sharing across the institute. The team should also study the societal needs and tune itself to cater to these needs. Industry-institute interaction would also pave the way to success.

Conclusion

When the environment in an engineering education system becomes dynamic and challenging, it automatically embraces the newer methods of managing knowledge. In such a situation, the strategic pull KM model can be very effective if implemented successfully.

Drawing upon the literature review of KM in various industries, the proposed KM flow model for engineering institutes gives a systematic method to create, validate, store, distribute and apply knowledge for productive outcomes within the premises of the integrated framework proposed in this paper. Also, knowledge mapping gives a structured flow of information thus supporting the knowledge architecture.

This paper underscores how engineering institutes can manifest their strategic dreams into reality through a systematic KM framework, which basically integrates technology, techniques and people for an effective management of the intellectual capital. While proposing the KM system, it also lists the implications for quality outcomes through effective implementation of the processes at each stage.

As Stewart & Kaufman [28] state: "*What's important is to find useful knowledge, bottle it, and pass it around".* The proposed conceptual framework, in the most basic sense, does exactly the same. But the success of it mainly depends on the management initiatives in creating a culture responsive to knowledge management and transforming the institution into a 'learning institution', where learning is a continuous and never ending process. In the long run the engineering institutions may even have to develop a global KM database, which can be accessed from any part of the world and collaborative efforts may be undertaken to seek solutions to Hi-tech problems.

"You don't have to do this; survival is not compulsory!" – E. Edwards Deming.

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References

1. T. Hellstrom T. and Husted K., Mapping Knowledge and Intellectual Capital in Academic Environments, Journal of Intellectual Capital, vol. 5 No.1, pp.165-180, Emerald Group Publishing Ltd. 2004. (Journal Paper).
2. M. Gibbons, C. H. Limoges Nowotny, et. al.. The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Society, Sage Publications, London 1994. (Book)
3. A. Zuckerman, and H. Buell, Is the world Ready for Knowledge Management? Quality Progress, Vol. 31, No. 6, pp. 81-84 (1998). (Journal Paper)
4. E. Turban, and J.E. Aronson, (Eds.) Knowledge Management, Decision Support Systems and Intelligent Systems, Pearson Education, ISBN 81-7808-367-1, pp. 344-393, 2002. (Book)
5. E. Smith, & M. Lyles, (Eds.), Knowledge Management, Handbook of Knowledge Management, Oxford: Blackwell Publishers, 2003. (Book)
6. M. Jacob, & T. Hellstrom, (Eds), Supporting University Structure, The Future Knowledge Production in the Academy, Open University Press, Buckingham 2000. (Book)
7. M. Castells, The Rise of Network Society, Oxford: Blackwell. p. 32, 1996. (Book)
8. M. Gloet, & M. Berrel, The dual paradigm nature of KM: implications for achieving quality outcomes in human resources management, Journal of Knowledge Management, vol. 7, No. 1, pp.78-89, ISSN 1367-3270, 2003. (Journal Paper)
9. M. Al-Ghassani, H. S. Robinson, P.M. Carrillo and C. J. Anumba, A Framework for Selecting Knowledge Management Tools, 3rd European Conference on Knowledge Management, Ireland, pp. 37-48 2002. (Proceedings)
10. Kaplan, S. Robert, Norton, P. David, Balanced Scorecard: Translating Strategy into; Harvard Business School Press Book; Product Number: 6513, 1996. (Book)
11. R. Mayer, T. Cullinane, P. De Witte, W. Knappernberger, B. Perakath, & S. Wells, ICCE IDEF3 Process Description Capture Method Report, (al/tr-1992-0057). Technical report, Air Force Systems Command, Wright-Pattersson Air Force Base, Ohio, 1992. (Report)
12. M. Ould, Introduction of Process technology, Series of articles on Strim/RADs, in I-opener, The Journal of the IOPT Club, V1:5, V2:1&3, 1993. (Journal)
13. B. Benus, Organisational modelling and Knowledge Management, Social Science Informatics, University of Amsterdam, Amsterdam 1993. (Bulletin)

14. G. Bhatt, A Resource-based Perspective of Developing Organisational Capabilities for Business Transformation, Knowledge and Process Management, vol. 7, No. 2, pp. 119-129. 2000. (Journal Paper)
15. D. Bhatt, Knowledge Management in Organisations: Examining the Interaction between Technologies, Techniques and People, Journal of Knowledge Management, MCB University press, ISSN-1367-3270, pp. 68-75, 2001. (Journal Paper)
16. C. K. Prahallad and G. Hamel, The Core Competence of an Organisation, Harvard Business Review, Vol. 86, No. 3, pp. 79-93, 1990. (Book)
17. G. M. Marakas,. Decision Support Systems in the 21st Century, prentice Hall, NJ: Englewood Cliffs, p. 440, 1999. (Book)
18. M. Alavi, and D. Leidner, Review: Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues, MIS Quarterly, Vol. 25, No. 1, pp. 107-136 2001. (Journal Paper)
19. Y. Malhothra, Integrating KM Technologies in Organizational Business Processes: Getting RTE to Deliver Real Business Performance, Accepted for publication in The Journal of KM Emerald publication, (2004). (Journal)
20. www.abet.org (website)
21. M. Polyani, Personal Knowledge, Chicago: University of Chicago Press. In Turban, E. & Aronson, J., E. (Eds.) (2002). Knowledge Management, Decision Support Systems and Intelligent Systems, Pearson Education, ISBN 81-7808-367-1, pp. 344-393, 1958. (Book)
22. C. W. Hossaple, and A. B. Winston,. Decision Support Systems: A Knowledge Based Approach, West Publishing, 1996. (Book)
23. E. Schein, Organisational Culture and Leadership, San Francisco: Jossey Bass, 1997. (Book)
24. K. Sherif, and M. Mandiwalla, Barriers to Actualizing Organisational Memories: Lessons from Industry, 33rd Hawaii International Conference on System Sciences, Loss Alamitos, CA: IEEE Computer Society Press, 2000, (Proceedings)
25. Vaas, Brainstorming, PC Week, Vol. 16, No. 22. In Turban, E. & Aronson, J., E. (Eds.) (2002). Knowledge Management, Decision Support Systems and Intelligent Systems, Pearson Education, ISBN 81-7808-367-1, pp. 344-393, 1999. (Book)
26. J.E. Orr, Talking about Machines: An Ethnography of a Modern Job, NY: ILR press. In Bhatt, G., D. (2001). KM in Organisations: Examining the Interaction between Technologies, Techniques and People, *Journal of Knowledge Management*, pp. 68-75. ISSN 1367-3270, 1996. (Book)
27. P. Galsser, The Knowledge Factor, In D. Bhatt, (2001), Knowledge Management in Organisations: Examining the Interaction between Technologies, Techniques and People, Journal of Knowledge Management, MCB University press, ISSN-1367-3270, pp. 68-75. (1998). (Journal Paper)
28. T. A. Stewart, and D. C. Kaufman, Getting Real about Brain power, Fortune. In, From Information Management to Knowledge Management: Beyond the Hi-tech Hidebound System, Information Today, pp. 37-61, Medford: NJ, 1995. (Book)

Appendix 1. Graduate Attributes

1. Self Development
2. Interpersonal skills
3. Professionalism
4. Research & Inquiry Skills
5. Critical Thinking
6. Knowledge Application
7. Design a system
8. Multi-disciplinary
9. Life-long learning

Appendix 2. Syllabus of a typical course (Mechanical Engineering)

<table>
<tr><td colspan="2" align="center">First Year</td></tr>
<tr><td>First Semester:
- MA-101—Engineering Mathematics-1
- CE-102—Engineering Mechanics
- EE-103—Basic Electrical technology
- HU-104---Communication Skills in English
- CY-105---Engineering Chemistry
- CS-106—Computer Programming
- CS-107---Computational Practice Lab
- CY-108--- Engineering Chemistry Lab
-</td><td>Second Semester:
- MA-201--- Engineering Mathematics-2
- CE-202---Strength of Materials
- EC-109---Basic Electronics
- ME-110—Mechanical Engineering Science
- PY-111--- Engineering Physics
- ME-112--- Engineering Graphics
- ME-113---Basic Metal Working Practice
- PY-114--- Engineering Physics Lab</td></tr>
<tr><td colspan="2" align="center">Second Year</td></tr>
<tr><td>Third Semester:
- MAT-201---Mathematics-3
- MEE-201—Material Science & Metallurgy
- MEE-203---Basic Thermodynamics
- MEE-205---Fluid Mechanics
- MEE-207---Production Techniques
- MEE-209---Mechanical Drawing-1
- MEE-211---Workshop Practice--1
- CIV-213---Material Testing Lab</td><td>Fourth Semester:
- MAT-202--- Mathematics-4
- MEE-202—Applied Thermodynamics
- MEE-204—Kinematics of Machinery
- MEE-206—Machine Tool Operation
- MEE-208---Mechanical Design-1
- MEE-210—Mechanical Drawing-2
- MEE-212--- Mechanical Lab-1
- MEE-214---Workshop Practice-2
-</td></tr>
<tr><td colspan="2" align="center">Third Year</td></tr>
<tr><td>Fifth Semester:
- MEE-301---Dynamics of Machinery
- MEE-303—Mechanical Design-2
- MEE-305---Turbo Machines
- MEE-307---Mechanical Design & Drawing
- MEE-309---Advanced Manufacturing Techniques
- MEE-311---Instrumentation & Metrology
- MEE-313—Mechanical Lab-2
- MEE-315---Machine Shop Practice-1</td><td>Sixth Semester:
- MEE-302—Heat Transfer
- MEE-304---Operations Research
- MEE-306---Automobile Engineering
- MEE-308—CAD/CAM
- MEE-310---Mechatronics
- HUM-301—Engineering Economics
- MEE-314---Metrology & Machine Tool Lab
- MEE-316—Machine Shop Practice-2</td></tr>
<tr><td colspan="2" align="center">Fourth Year</td></tr>
<tr><td>Seventh Semester:
- MEE-401---Elective-1
- MEE-403--- Elective-2
- MEE-405---Production/Operation Management
- MEE-407---Mechanical Vibrations
- MEE-409---Energy Systems
- HUM-401---Essentials of Management
- MEE-411---Mechanical Lab-3
- MEE-413---CAD/CAM Lab</td><td>Eight Semester:
- MEE-412---Technical Seminar
- MEE-414---Industrial Tour
- MEE-499---Practice School</td></tr>
</table>

Appendix 3

KM technologies classified by KM sub-processes (Source: Al-Ghassani et al 2002)

Author	KM Sub-processes	KM Technologies
Jackson (1998)	Gathering	Pull, Searching, data entry /OCR
	Storage	Linking, Indexing, Filtering
	Communication	Sharing, Collaboration, Group Decisions
	Dissemination	Push, publishing, notification
	Synthesis	Analysis, Creation, Contextualisation
Laudon & Laudon (2000)	Creation	Knowledge work system: Computer Aided Design (CAD), Virtual Reality, Investment Workstations.
	Knowledge capturing & codifying	Artificial intelligence Systems: Expert Systems, Neural Nets, Fuzzy Logic, Genetic Algorithms, and intelligent Agents.
	Knowledge distribution	Office Automation Systems: Word Processing Desktop Publishing Imaging & Web Publishing Electronic Calendars, Desktop Databases.
	Knowledge sharing	Group collaboration Systems: groupware, intranets.
Tsui (2002a)	Creation	Associative links, information capturing & sharing, Concept/ Mind Mapping.
	Codification/ Representation	Associative links, Information capturing & sharing, Concept/Mind Mapping E-mail Management, Analysis & Unified.
	Classification/ Indexing	Index/ search, Meta-search, Associative Links, information Capturing & sharing, Concept/ Mind Mapping, E-mail Managing, analysis & Unified.
	Search & Filter	Index/Search, Meta-search, E-mail management, Analysis & Unified.
	Share/Distribute	Index/ search, Meta-search, Associative Links, information capturing & sharing E-Mail Management, Analysis & unified.

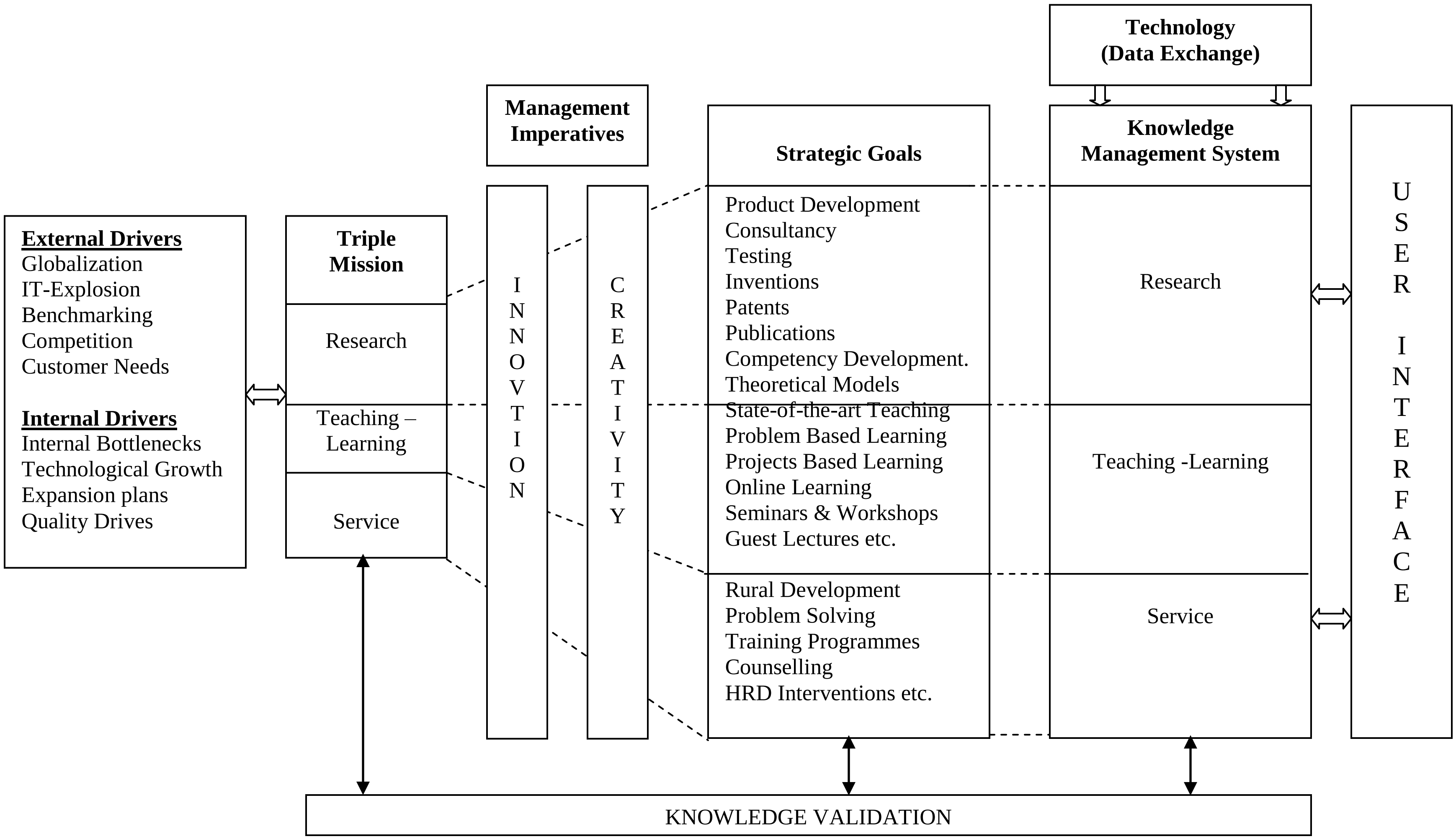

Figure 1. Conceptual Integrated Framework for Knowledge Management in Engineering Institute

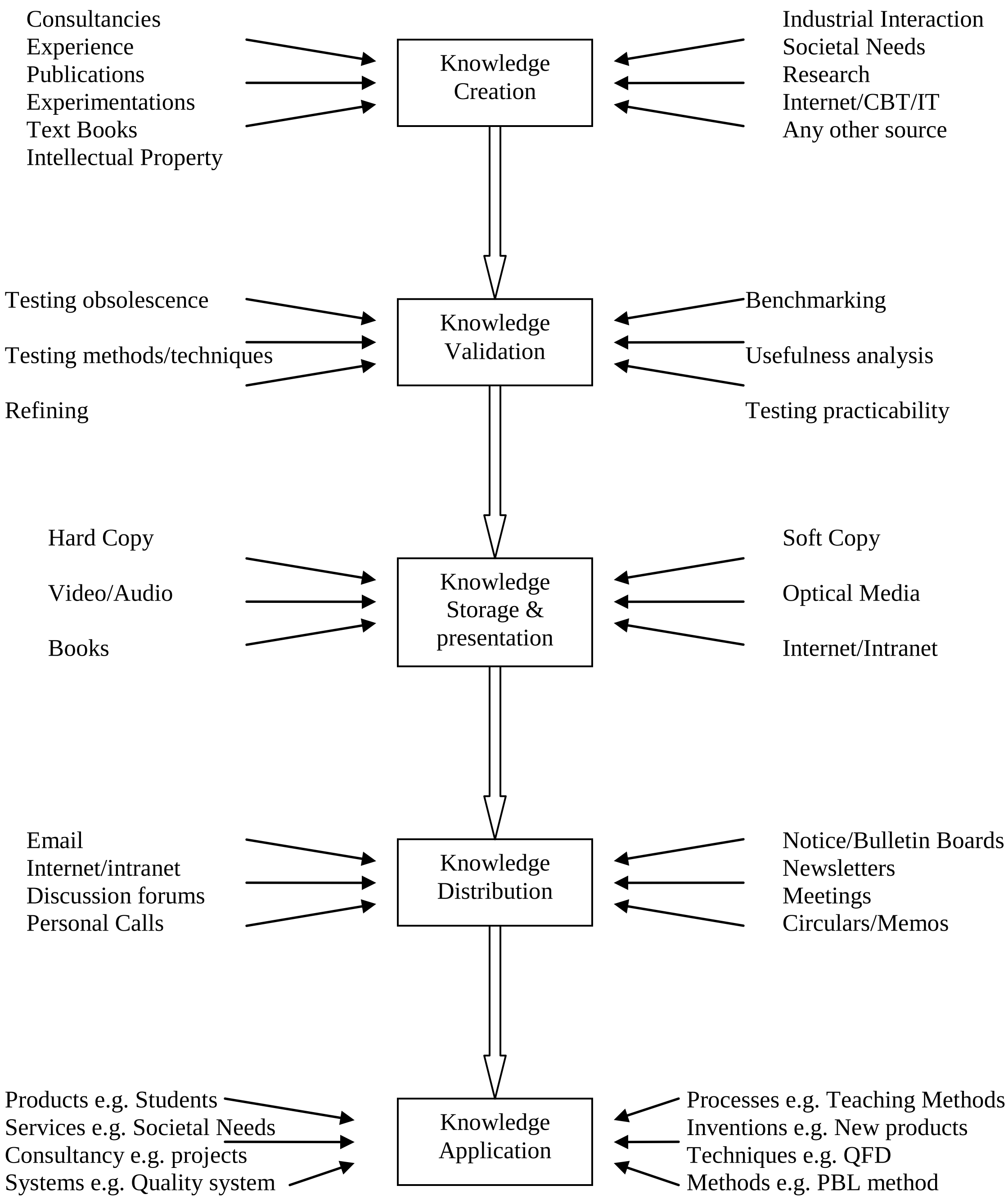

Figure 2. Knowledge Flow Pattern in Engineering Education

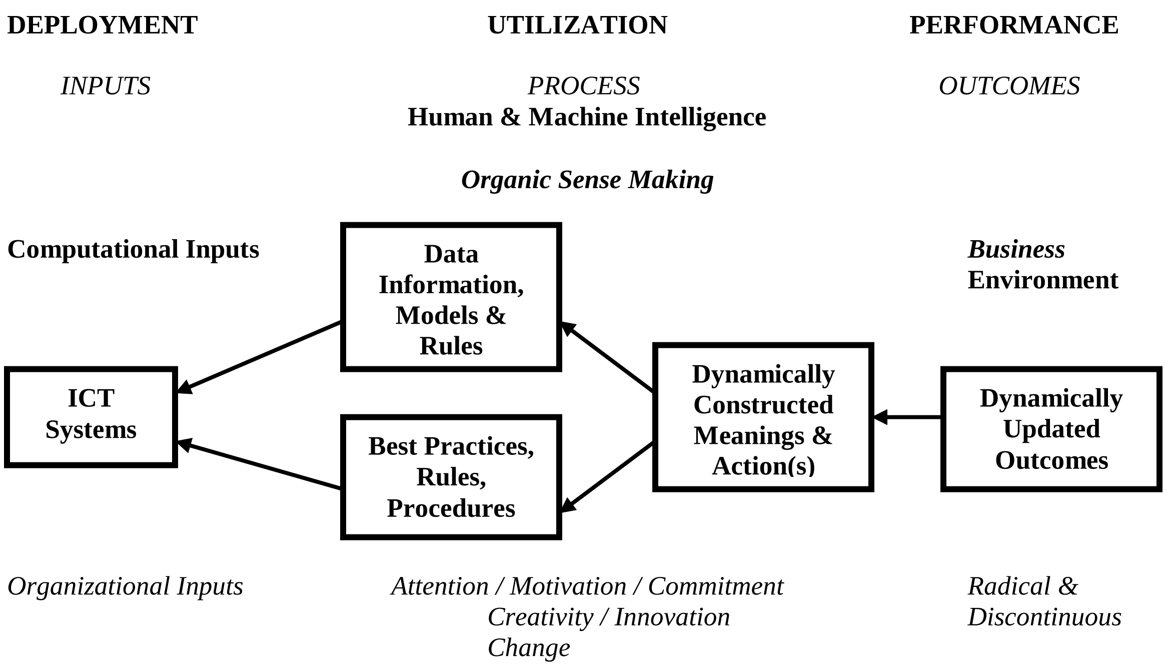

Figure 3. Strategy- pull Model of KM (Source: Malhotra, 2004 [19])

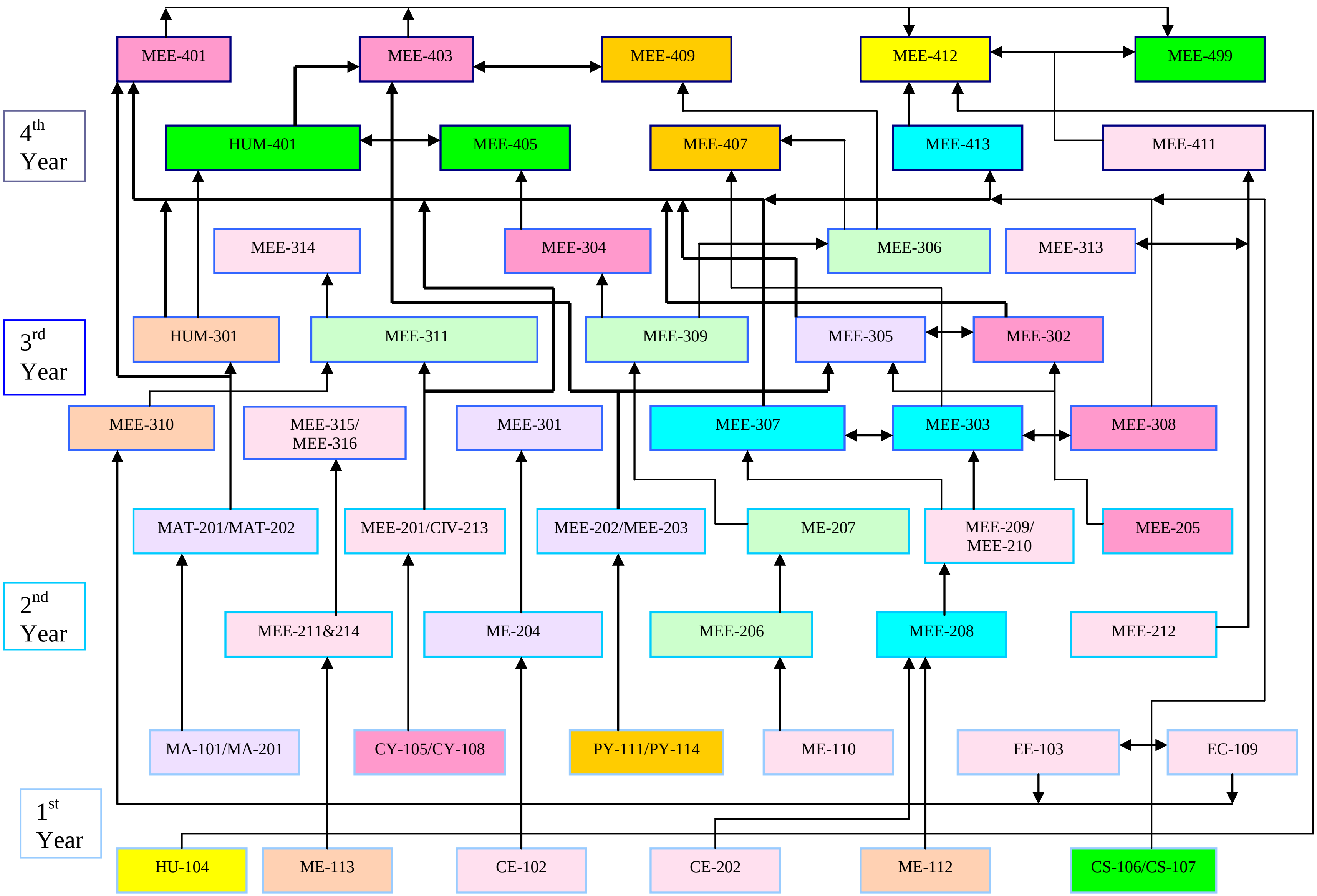

Figure 4. The Knowledge Map of Graduate Attributes