Computational Approaches to Competency Mapping: A review of literature

Sushri Samita Rout[a], Bijan Bihari Misra[b], Sasmita Samanta[c]
[a]Department of IT, Silicon Institute of Technology, Bhubaneswar, Odisha, India
[b]Department of IT, Silicon Institute of Technology, Bhubaneswar, Odisha
[c]KIIT University, Bhubaneswar, Odisha

Corresponding author: Sushri Samita Rout

Abstract

In the wake of globalization & rapid industrialization on one hand and growing concerns about sustainability on the other hand, it becomes imperative to think about the global economy and its relatively constant state of flux. If we consider any organization today it has a three-fold objective- maximize profit, minimize cost and last but not the least, in the process do minimum damage to the environment. If the objectives are so clear and crisp, why do organizations fail to do so? There would be a number of reasons attributed- financial crunches, improper planning, incompetent workforce, lack of vision, lack of a unique value proposition, lack of agility, lack of proper information dissemination to name a few. But these are reasons that are apparent. If we closely examine each reason, it will be evident that the source of fault lies in a human or human action. Whatever may the level of automation in terms of production, planning or decision making be, ultimately it's a human being who decides and acts. So at the crux of every scenario there are human resource/resources. But the question is why do they go wrong? Aren't they qualified? Do they lack the required skill set and attitude? Are they in the wrong place? Are they not equipped with the right quality and quantity of information? Right now organizations across the globe are facing a dichotomous situation- one is the issue of unemployment and the other is the issue of un-employability. Hence this study will explore the basic premise that is competency but in terms of the computational approaches that can be used to solve problems related to mapping competency.

KEYWORDS: Competency mapping, computational approaches, evolutionary computing**.**

A. Introduction

In the context of un-employability it would be worthwhile to mention that the major chunk of the unemployable people is technically qualified. In the year 1973, David McClleland (Professor, Harvard University) coined the idea of Competency **(McClelland, 1973)**. Since then several stalwarts have rendered different meanings to the word for different settings and contexts. But if considered in a generic sense, Competency comprises an entire gamut of attributes in terms of skills, knowledge and attitude required to perform a particular job and most important those attributes must be measurable. Various studies have largely attributed lack of competence as the prime reason behind the menace of un-employability. Then the question arises it is whose

responsibility to inculcate those competencies. Can those competencies be developed through training? How to measure them? How to use them in the appropriate setting?

At this point we come to the objective of our study. In the past several models of competency have been proposed, techniques have been laid for mapping competencies, assessment tools have been designed but there is very less literary evidence to suggest the successful application of those models and techniques in organizations. Furthermore one of the most important aspects of competency is its measurability. Though some computational models have been proposed for the process of competency mapping and its components, again there is lack of evidence regarding their efficiency and successful application. This situation necessitates the requirement for alternate proven techniques like evolutionary computing, artificial neural network and fuzzy techniques to be applied in the field of competency mapping, which would result in precise and objective information. In this chapter we will focus on certain unexplored facets of the process of competency mapping. We will start with a brief text on the methodological aspects of our study and then move on to a generic review on competency, competency mapping, its categorization and models. Thereafter we will present the trends in competency mapping, applications, techniques used for Competency Mapping. Then we will discuss several computational models that are currently being applied in several domains followed by computational approaches to Competency Mapping, Nature of Competency Mapping Problems and the appropriateness of Evolutionary Computing approaches. Finally we conclude our review with our inferences and gaps in terms of scope for future study.

B.Methodology

To give shape to the meandering course of any research/study it is essential that a well-defined methodology be followed. For this particular review different journal and conference papers and articles were searched. A review usually covers a large number of domains and applications because of its pervasive nature. This is required for the construction of a sound base on which further studies can rely. Otherwise the very objective of the study will be defeated. On the basis of the computational tools and the area of application, it is evident that the study is an amalgam of technical and management research. Considering both the aspects we focused our search on the following e-resources and databases. We have tried to make the search as exhaustive as possible, but sometimes we were constrained from the accessibility point of view.

- IEEE Xplore (IEE/IEEE)
- Springer Link
- Elsevier
- Emerald Insight
- Open Information Systems Journal
- Business Source Premier (EBSCO)
- Journal of Enterprise Information Management
- Issues in Information Systems
- Communications of ACM

Articles for the proposed construct i.e. competency mapping were searched using the keywords competency and competency mapping. Initially we got a huge number of articles as the years of search were not restricted to some time period. So the articles were filtered in terms of their year of publication starting from 2005 onwards, but cross-references dated to earlier years were reviewed and included in the study. For the purpose of finding computational approaches, no filter was applied as there are very few articles published. In this case the key words used are – competency, mapping, and human resource management, computational and evolutionary. After the initial selection of articles, the abstracts and conclusions were studied for final consideration. The articles chosen in this process were thoroughly studied for content analysis, which form the basis of our review. Most of the studied literatures have collected their data from secondary sources and the available organizational literature and through unstructured interviews with the domain experts (Cohen, 1989) (Milutinovic, 1995).

C. Competency

After David McClelland proposed the idea of competency in the early 70's, several prominent scholars and researchers have provided various interpretations and applications. The fact that different assignments and projects require different level of knowledge and different set of skills was highlighted by Quinn (Quinn, 2003). Spencer and Spencer laid ground for the use of competency in education, business and human resource management (Spencer, 1993). Furthering the work of several scholars Spencer and Spencer focused on the underlying characteristics that affect an individual's job performance and also proposed the Job Competence Assessment Method. In the late 90's competency was defined more objectively where it included underlying qualification and attributes of individuals, observable behaviors and the level of individual performance outcomes (Hoffmann, 1999) . Later on, apart from the standard success factors other factors like attitudinal aspects, mental and physical traits were considered a crucial part of any job description (Nahavandi, 2009) (Hayward, 2002).

The definitions and concepts that have been laid by different researchers are somewhere intertwined. Basically we can define competency:

- As a collection of those attributes that people have or can acquire.
- Attributes that can be applied as thoughts and action which will in turn manifest as behavior.
- Behavior in turn produces outputs in terms of products and services where not only the ends but the means or the process of yielding the output is also important (Shermon, 2004).
- Ability to be assessed and measured

D. Competency Mapping

Competency Mapping on one hand is the process of identifying an individual's skills and abilities in terms of their relative strengths and weakness, find the existing gap, determining the training and development requirements for an individual and on the other hand, identifying the competency requirements in an organization in terms of job, interpersonal and organizational requirements. The prime application of this process is

putting the right person in the right place at the right time. Traditionally this process has been accomplished using the concepts and techniques of 'Job Evaluation', 'Role Profiling', 'Expert Panels', 'Organizational Surveys', '360 degree multi-rater feedback', 'Repertory grid system', 'Behavioral event interview' and 'Rank order' to name a few . Several assessment and identification techniques like Formative and Summative Assessment, Norm Referencing and Criteria Referencing, Performance Assessment, Self \& Peer Assessment etc for the process have been devised and proposed in the recent years . Some of the prominent ones currently being adopted are Complete Personality Typology, Classification and job-suitability analysis (Shermon, 2004).

Applications of competency mapping

In this section we present the applications of competency mapping from the perspective of its usage irrespective of the domain or industry. Below we present the different ways in which the results can be used or the relevance and usage of competency mapping in Human Resource Management. Competency mapping can be used as a foundation to develop and enhance the following activities (Shermon, 2004)(Stevenson, 2010) (Muller, 2010)(Manasa, 2009)(Abu, 2007)(Shermon 2004).

- Design of Role Directories
- Design of performance appraisal systems
- Training and development plan
- Recruitment and selection
- Human resource information system

Techniques/Assessment Scales used in competency mapping

Several techniques have been devised in the past years. Some of the most prominent techniques that are widely used across disciplines and industries that are widely used are: Behavioral Event Interview, Assessment Centers, Repertory Grid, Critical Incident Technique, 360 degree feedback and STAR (Flanagan, 1954). There are three widely used scales used to evaluate an individual against a said competency namely – Likert, Behaviorally Anchored Rating Scales and Threshold Scales (Shermon 2004).

Nature of competency mapping problems

In today's world one would hardly find a problem, which is single-objective. Numerous times we encounter problems or situations, where one cannot find a single right solution, which takes care off or optimizes all the objectives simultaneously. Most of the real-world problems are multi-objective, where conflicting objectives along with a number of constraints make it difficult to select a particular approach or solution. There are instances of a wide range of problems in a variety of fields, which need a trade-off between the conflicting objectives. For instance, in order to maximize profit the cost of production needs to be reduced, but given the constraints, reduction in the cost of production means, compromising on the quality of the product. So the problem is how do we balance and optimize those conflicting objectives in order to get a suitable solution. There are numerous such problems in the field of automobile \& aircraft design, wireless networks, vehicle routing, process and production set-ups, oil industry, financial and

economical policy design which are candidates for being optimized using multi-objective optimization. The problem that we have considered for our study quite fits to be a candidate for being solved using optimization and inference tools. Hence in the subsequent sections we will discuss widely used computational models and some very specific applications of those models to competency mapping and related problems, as per reviewed literature.

E. Computational Models

There are several computational models which can be applied in the domain of competency mapping quite successfully. In the following section we briefly discuss some of the models.

1. Artificial Neural Networks: Artificial Neural Networks are inspired by the central nervous system of human beings and is a unit of computational neuro-science. It's an adaptive network in the sense that it can learn and re-orient its structure based on the input and output. It is organized in the form of layers which are made of inter-connected nodes. These models work well for finding associations, uncovering patterns, and bringing clarity to complex non-linear relationship between variables, prediction and optimization etc. Adaptivity and learning ability are the USPs of the technique. One of the associated drawbacks of ANN is its black-box nature, overhead computational burden and over-fitting. Currently ANNs are being used in a wide range of data-intensive domains ranging from finance, medical, sales marketing, supply chain, human resource, education and science to energy, agriculture and sports (Tu, 1996).
2. Fuzzy Logic: Fuzzy logic is a set theory concept conceptualized by Lofti Zadeh, of University of California, Berkley. It allows for processing of data using partial set membership. It is known for effectively handling ambiguous, vague and imprecise information. But the crux is it handles and processes subjective information very fast. It is credited to have many successful implementations in process control systems. Fuzzy logic implementations range from micro-controllers, data acquisition and control systems to preference modeling, information retrieval, and robotics, nuclear and medical engineering as well (Zadeh, 1963) (Eiben, 2003).
3. Evolutionary Computation: Evolutionary Computation is a field of computational system, which takes inspiration from the theory of natural or biological evolution. The systems are based on the evolutionary process of reproduction, natural selection and Darwin's principle of 'Survival of Fittest'. Over the years several evolutionary computing approaches have been devised each with its own set of advantages and disadvantages. Some of the prominent ones are discussed below:
4. Genetic Algorithm: It is a heuristic search algorithm formulated by Holland, for arriving at an optimum solution from a pool of candidate solutions using Darwinian principle - 'Survival of the Fittest'. The candidate solutions are represented using bit strings which go through the cross-over, selection and mutation operations.
5. Genetic Programming: Genetic Programming was invented by Cramer in 1985, involves the evolution of computer programs or program like executable

structures. Basically it searches a program space instead of a solution space to the optimal program to implement a user-defined task. Here the computer programs to be evolved are represented in form of trees using cross-over and mutation operations. It is typically used for machine learning and modeling (Raghavjee, 2012).

6. Evolutionary Programming: evolutionary programming was devised by Fogel et al in the mid 1960s , which doesn't use a fixed program structure like Genetic Programming. Initially it was used in finite state automata for machine learning. In evolutionary programming each parent generates an off-spring using mutation as the main variation operator. It is successfully used in a wide range of optimization problems (Aziz, 2013).
7. Evolution Strategies: Evolution strategies were initially proposed by Rechenberg and Schwefel for discrete parameter optimization. It uses the technique of self-adaptive mutation. Here real-valued vectors are used to represent individuals.
8. Differential Evolution: Differential evolution is a global optimization technique proposed by Storn and Price. This technique uses cross-over, mutation and selection operations where mutation plays a crucial role. It is used for multi-dimensional real valued functions. Its applications include parallel computing and optimization including multi-objective and constrained optimization (Storn, 1997).
9. Differential Search Algorithm: SA is a kind of evolutionary algorithm for optimization of real-valued numeric problems. It was proposed by Civicioglu and simulates a super-organism that migrates between two stop-overs due to climate change. It has successfully yield optimal solution in the field of navigation, geodetic and astro-geodetic problems. Statistical tests have proved the efficacy of the methods over other methods in global optimization problems (Liu, 2014).
10. Swarm Intelligence: Swarm Intelligence represents those computational intelligence techniques which are based on the collective behavior and local interaction, done by a group of individuals. Some of the prominent and widely used swarm intelligence techniques are (Eiben, 2003) .
11. Particle Swarm Optimization: This technique was proposed by Eberhart and Kennedy in the year 1995. It is a stochastic optimization technique which imitates the behavior of flocks of birds or fishes. In this technique each bird represents a particle or solution in the search space. The solutions fly through the search space and veer towards the food source, which is the objective. The technique is known for its simplicity, efficiency and applicability to a wide range of application but is limited due to premature convergence (Hakli, 2014).
12. Ant Colony Optimization: It is a swarm intelligence computational model which mimics the behavior of an ant colony. It is based on the facts that ants deposit a chemical called pheromone on the ground to indicate about a preferable path (mostly the shortest path) that can be taken by other members of the colony. It was proposed by Marco Dorigo in the year 1992 and since then has been successfully applied to vehicle routing, combinatorial optimization problems, quadratic assignment and network routing problems. One of the landmark applications of ACO has been to produce near optimal solutions for the Travelling Salesman Problem. Years of research have revealed that ACO is a

powerful optimization tool for solving complex combinatorial problems, but is also attributed with uncertainty in the time required to converge (Dorigo, 2010).

13. Bacteria Foraging Optimization: BFO is yet another swarm optimization technique proposed by Passino which models the group foraging policies of the bacteria E-Coli(Escherichia Coli). This is based on the elimination of entities with poor foraging capabilities either by replacement of those entities or by enhancing those entities using desirable strategies. Here foraging refers to the small steps taken by the bacteria while searching for nutrients. It is basically applied in distribution optimization and control problems and can be successfully hybridized with many other meta-heuristic algorithms such as PCO \& GA. But the algorithm has been criticized for being structurally too complex (Munoz, 2010).
14. Honey Bee Algorithm: It is also a swarm based approach to optimization developed in 2001 by Abbass, based on the mating of Honey Bees. In this technique a colony of bees represents the population which search for food in the search space. Each time an agent bee encounters a solution it evaluates its fitness and the process continues iteratively. It has been successfully applied in clustering systems and classifiers, manufacturing, bio-engineering and many other Multi-objective optimization problems. It can be easily hybridized and has strength in both local and global search, but requires tuning of several parameters. There are several variants of bee-inspired algorithms namely: Artificial Bee Colony(ABC), Queen Bee(QB) and the fast marriage in Honey Bee Optimization (FMBO) (Vakil, 2010).

F. Computational approaches to competency mapping

The past few years have seen a sea change in the implementation of competency mapping. The power of computation has brought the much needed objectivity into the process. Several researchers have proposed computational approaches for the purpose of competency mapping, though the efficacy is yet to be established through published research. Some of the reported methods are given below which aid in the process of Competency Mapping.

Ping & Xiang in their work demonstrated the application of Expertise Knowledge Map in Human Resource Management. Expertise Knowledge Maps are visual tools represented as a map where each node indicates the knowledge and skills of an expert, and the line connecting the nodes represents the social capital of the experts. Such a tool readily helps in locating expertise in a particular skill set and can be used for HR planning, allocation, performance and compensation management etc. The tool is quite flexible in terms of visualization and can act as an excellent competency mapping tool. Self Organizing Maps (SOM) introduced by Kohonen and multi-dimensional scaling algorithms are the two most widely reported visualization techniques. (Kohonen, 1998) (Liu, 2011).

Suhem et al in their work regarding application of Data Mining in educational databases for predicting academic trends and patterns, indicated the use of a-priori and k-means clustering algorithm for student profiling and grouping in the process of data mining. The technique helps in extraction of association rules between set of items. This kind of profiling can be used for scheduling and prediction. The a-priori algorithm is used to find

dependencies between data items, while k-means is used to cluster objects into different partitions. These techniques can be safely used to cluster and discover hidden patterns which in turn help in profiling of employees (Parack, 2012).

Pooja and Jayanthi presented an expert system approach for the process of competency mapping, in their work, "Competency Mapping for Educational Institution: Expert System Approach". An Expert System is a computer-based information system that simulates the intelligence of human experts. The system acts as an expert consultant in a specific situation. In this work the authors have presented a comprehensive design methodology for the development of an expert system for educational institutes. The knowledge base consists of rule-based data to be used for competence and performance management. The inference engine can be constructed using commercially available expert system shells like ESIE \& Level 5 Object etc (Tripathi, 2010)

Nur et al, proposed the Analytical hierarchy Process (AHP) for selection of new lecturers. Several MCDM (Multi Criteria Decision Making) techniques like weighted sum model, analytical network process and Electre etc have previously been used for the purpose. But AHP is reported for exhibiting combined benefits of both qualitative and quantitative approaches, which have the ability to measure both tangible and intangible criteria. In this work the authors have proposed a model based on AHP where the computation is handled using excel spreadsheet. Here five levels of hierarchy have been considered starting from the goal, types of interview, criteria, sub-criteria and finally the candidates. Scores are assigned for each criterion and pair-wise comparison matrix is constructed. Thereafter the matrix is normalized and tested for consistency (Norddin, 2012) .

G. Evolutionary computing approaches to competency mapping

V Shahhosseini and M H Sebt in their work, "Competency-based selection and assignment of human resources to construction projects" presented a method to model the selection and assignment of construction project personnel, which are classified into four types: Project Manager, Engineer, Technician and Laborer. The proposed model integrates a fuzzy logic qualitative approach and neural network adaptive capabilities to evaluate and rank construction personnel based on their competency. Results from this system in personnel staffing show the high capability of the model in making a high quality personnel selection (Shahhosseini, 2011).

G Meenakshi in her work, "Multi source feedback based performance appraisal system using Fuzzy logic decision support system", has mentioned some criteria \& sub-criteria's to evaluate the performance of teaching staff, which can be considered as a indicative guideline for selecting different skill sets of a faculty (Meenakshi, 2012).

I-Tung Yang and Jui-Sheng Chou, in their work "Multi-objective optimization for manpower assignment in consulting engineering firms" proposed a multi-objective optimization model – MUST, to facilitate the staff-to-job assignment in consulting engineering firms. In addition to the typical objective of maximizing profits, other human resource related objectives were also incorporated to balance workloads, avoid excessive overtime, and eliminate demoralizing idleness while giving preference to projects with specified priorities. It has been shown that non-dominated solutions generated by MUST

helped decision makers choose the compromised assignment plan which is otherwise hard and time-consuming to obtain, which makes it an lucrative approach for solving MCDM(Multi-Criteria Decision Making) problems (Yang, 2011).

Shao-Qiang, Li-Hua \& Shi-Liang, in their paper "The Allocation Optimization of Project Human Resource Based on Particle Swarm Optimization Algorithm" emphasized on an aspect that, a situation with employees working on tasks that they are not well-suited for can lead to a significant loss of time and resources in addition to a sub-par product or service. Those that do take employee preference into consideration are non-deterministic, thus making it more difficult to evaluate the business process in an efficient manner. They presented a project human resource allocation method based on particle swarm optimization (PSO) in a project organization, by developing a mathematical model of project human resource optimization allocation using the competency model theory, and then in order to obtain a solution efficiently, proposed a particle swarm optimization algorithm (PSO) approach based on the decision-making model for solving the allocation optimization problem of project human resource. According to the proposed method, they applied the PSO to seek feasible solution for the problem. The effectiveness of the proposed algorithm was validated by its application to an illustrative example dealing with project human resource allocation problem (Wang, 2009).

Zhengyuan Jia and Lihua Gong in their work "Multi-criteria Human Resource Allocation for Optimization Problems Using Multi-objective Particle Swarm Optimization Algorithm" proposed the MOPSO approach for optimal human resource allocation using the competency model theory where the objective was to seek an optimal allocation of a limited amount of resource (person, asset, material or capital to a number of tasks for optimizing their objectives subject to the given resource constraint (Gong, 2008).

WANG Qing & ZHENG in their work "Optimization of Task Allocation and Knowledge Workers Scheduling Based-on Particle Swarm Optimization" stressed on scientific task allocation and knowledge workers scheduling is an important part of rational human resources management in enterprises. According to their research there are two types of research objects. One type of research objects is homogeneous skilled workers, which is mainly concentrated in nurse scheduling, staff scheduling for call centers, home care workers scheduling, aircraft routing and crew scheduling, etc. The common characteristics of the above researches: homogeneous skilled workers take on homogeneous tasks; staffing process does not involve task allocation, only include workers scheduling. This kind of problem is relatively simple. Results of these researches apply only to scheduling homogeneous workers in specific industries, and do not have universality. The other type of research object is heterogeneous skilled workers. Since 2006, they have researched characteristics of task allocation and knowledge workers scheduling, and proposed a method based on genetic algorithm to solve conventional task allocation and knowledge workers scheduling. The method has solved the problem to a certain degree, but it still has drawbacks, such as slow search and prematurity (Qing, 2011).

Ho et al, demonstrated the utilization of PSO in student grouping problems, where the objective was to form a group comprised of the right kind of students. They used an

enhanced particle swarm optimization algorithm to arrive at the solution and used CPLEX (integer programming optimizer) to compare the efficiency and accuracy of the solutions arrived at by the PSO simulation. The comparison results indicated that the PSO showed better performance in terms of fitness acquisition and the time required for processing (Ho, 2010).

Julian et al proposed yet another approach for student group formation in collaborative learning taking into account multiple student characteristics. The method was experimented using three student characteristics namely; student knowledge levels, communication skills and leadership skills. These characteristics were used to from groups which were converted into a multi-objective optimization problem. The objective was to achieve inter-homogenous and intra-heterogeneous student groups, so that there is a balance in all the groups in terms of its characteristics. This work can be used for load or task allocation, training need identification not only in students but also in employees of an organization (Moreno, 2012).

H. Conclusion

In the last decade lot many studies have been carried out in the area of Competency Mapping. But it is clearly evident that there is a substantial lack of literature to validate most of the findings. Many techniques, methods, computational approaches have been proposed, but there is neither any study implementing the techniques proposed, using information from primary sources nor any case study to demonstrate the usage. It would not be wrong to state that absolutely no work has been done to exploit the power of computational tools in the field of competency mapping. Few of the researchers have applied some evolutionary computing techniques for the purpose of tack allocation, but not beyond that. Hence a huge gap exists in terms of research as well as application if we consider Competency Mapping and the suitability of the computational approaches to it. There exist a lot of avenues for further study and research which will be highly beneficial in many aspects. Considering the generic nature of both the domain (Competency Mapping) and computing tools, it can be safely inferred that this kind of research will have wide span of applications. Below we present some of the generic research directions in this field.

- Devise scientific assessment, evaluation, and load allocation techniques using computational approaches.
- Conduct longitudinal studies to validate the findings of different studies.
- Computational tools may be used to profile employees, students etc based on competence parameters. Further these profiles could be used for training need analysis and a plethora of other development activities.
- Studies can also be conducted to categorically identify the employability skills lacked, profile the attributes that contribute to the lack and suggest preventive measures.

Apart from the above mentioned directions, lots of untapped directions are there. So we would like to tap this hugely untapped avenue in this work.

References

1. Aziz, N. I. A., Sulaiman, S. I., Musirin, I., & Shaari, S. (2013, June). Assessment of evolutionary programming models for single-objective optimization. In *Power Engineering and Optimization Conference (PEOCO), 2013 IEEE 7th International* (pp. 304-308). IEEE.
2. Cohen, P & Howe A (1989). Towards AI ResearchMethodology: Three Case Studies in Evaluation. IEEE Transactions on Systems, management and Cybernetics. Vol.19, #3, 634-646
3. Dorigo, M., Birattari, M., & Stützle, T. (2006). Ant colony optimization.*Computational Intelligence Magazine, IEEE*, *1*(4), 28-39.
4. Eiben, A. E., & Schoenauer, M. (2002). Evolutionary computing. *Information Processing Letters*, *82*(1), 1-6.Abu-Doleh, J. & Weir, D. (2007). Dimensions of performance appraisal systems in Jordanian private and public organizations. *International Journal of Human Resource Management, 18(1),* 75-84.
5. Flanagan, J. C. (1954) .The critical Incident Technique, Psychological Bulletin, 5(4), 327-358.
6. Haklı, H., & Uğuz, H. (2014). A novel particle swarm optimization algorithm with Levy flight. *Applied Soft Computing*, *23*, 333-345.
7. Hayward, G. B. (2002).*Developing a competency model-based maintenance manager qualification program utilizing concept mapping methodology*, Unpublished doctoral dissertation, Capella University, Minneapolis, MN.
8. Ho, T. F., Shyu, S. J., & Li, C. T. (2010, July). Utilizing Particle Swarm Optimizations on student grouping problem. In *Machine Learning and Cybernetics (ICMLC), 2010 International Conference on* (Vol. 4, pp. 1899-1904). IEEE.
9. Hoffmann, T. (1999). The meanings of competency. *Journal of European Industrial Training*, *23*(6), 275-285.
10. Jack V. Tu, Advantages and disadvantages of using artificial neural networks versus logistic regression for predicting medical outcomes, Journal of Clinical Epidemiology, Volume 49, Issue 11, November 1996, Pages 1225-1231
11. Jia, Z., & Gong, L. (2008, December). Multi-criteria human resource allocation for optimization problems using multi-objective particle swarm optimization algorithm. In *Computer Science and Software Engineering, 2008 International Conference on* (Vol. 1, pp. 1187-1190). IEEE.
12. Kohonen, T. (1998). The self-organizing map. *Neurocomputing*, *21*(1), 1-6.
13. L. A. Zadeh. Fuzzy sets. Information Control, 8:338–353, 1965.
14. Liu, B. (2014). Composite Differential Search Algorithm. *Journal of Applied Mathematics*, *2014*..
15. Liu, P., & Li, X. (2011, August). The Application of Expertise Knowledge Map in Human Resource Management. In *Management and Service Science (MASS), 2011 International Conference on* (pp. 1-4). IEEE.
16. Manasa, K. & Reddy, N. (2009). Role of Training in Improving Performance. *The IUP Journal of Soft Skills, 3,* 72-80.

17. McClelland, D. C. (1973). Testing for competence rather than intelligence. *American Psychologist*, *28*(1), 22-26.
18. Meenakshi, G. (2012). Multi source feedback based performance appraisal system using Fuzzy logic decision support system. *arXiv preprint arXiv:1203.1882*.
19. Milutinovic, V.(1995). A research Methodology in the field of computer engineering for VLSI. 20th INTERNATIONAL CONFERENCE ON MICROELECTRONICS. Vol.2. Serbia.811-816
20. Moreno, J., Ovalle, D. A., & Vicari, R. M. (2012). A genetic algorithm approach for group formation in collaborative learning considering multiple student characteristics. *Computers & Education*, *58*(1), 560-569.
21. Muñoz, M., Halgamuge, S. K., Alfonso, W., & Caicedo, E. F. (2010, July). Simplifying the bacteria foraging optimization algorithm. In *Evolutionary Computation (CEC), 2010 IEEE Congress on* (pp. 1-7). IEEE.
22. Nahavandi, A. (2006). *The art and science of leadership* (4th ed.), Upper Saddle River, NJ: Merrill/Prentice Hall.
23. Norddin, N. I., Ibrahim, K., & Aziz, A. H. (2012, September). Selecting new lecturers using the Analytical Hierarchy Process (AHP). In *Statistics in Science, Business, and Engineering (ICSSBE), 2012 International Conference on* (pp. 1-7). IEEE.
24. Parack, S., Zahid, Z., & Merchant, F. (2012, January). Application of data mining in educational databases for predicting academic trends and patterns. In*Technology Enhanced Education (ICTEE), 2012 IEEE International Conference on* (pp. 1-4). IEEE.
25. Qing, W., & Han-chao, Z. (2011, April). Optimization of task allocation and knowledge workers scheduling based-on particle swarm optimization. In *Electric Information and Control Engineering (ICEICE), 2011 International Conference on* (pp. 574-578). IEEE.
26. Quinn, E. R., Faerman, R. S., ThomPSOn, P. M., & McGrath, R. M. (1990). *Becoming a master manager: A competency framework*, New York: John Wiley & Sons.
27. Raghavjee, R.; Pillay, N., "A comparison of genetic algorithms and genetic programming in solving the school timetabling problem," Nature and Biologically Inspired Computing (NaBIC), 2012 Fourth World Congress on , vol., no., pp.98,103, 5-9 Nov. 2012
28. Ralf Müller, Rodney Turner, Leadership competency profiles of successful project managers, International Journal of Project Management, Volume 28, Issue 5, July 2010, Pages 437-448, ISSN 0263-7863,
29. Shahhosseini, V., & Sebt, M. H. (2011). Competency-based selection and assignment of human resources to construction projects. *Scientia Iranica*,*18*(2), 163-180.
30. Shermon, G.2004. *Competency based HRM*, Delhi. : Tata McGraw Hill.
31. Spencer, L., & Spencer, M. (1993). *Competence at work: Models for superior performance*, N.Y.: John Wiley & Sons.
32. Stevenson, D. H., & Starkweather, J. A. (2010). PM critical competency index: IT execs prefer soft skills. *International Journal of Project Management*, *28*(7), 663-671.,

33. Storn, R., & Price, K. (1997). Differential evolution–a simple and efficient heuristic for global optimization over continuous spaces. *Journal of global optimization*, *11*(4), 341-359.
34. Tripathi, P., & Ranjan, J. (2010). A Competency Mapping for Educational Institution: Expert System Approach.
35. Vakil-Baghmisheh, M. T., & Salim, M. (2010, December). A modified fast marriage in honey bee optimization algorithm. In *Telecommunications (IST), 2010 5th International Symposium on* (pp. 950-955). IEEE.
36. Wang, S. Q., Gong, L. H., & Yan, S. L. (2009, July). The allocation optimization of project human resource based on particle swarm optimization algorithm. In*Services Science, Management and Engineering, 2009. SSME'09. IITA International Conference on* (pp. 169-172). IEEE.
37. Yang, I. T., & Chou, J. S. (2011). Multiobjective optimization for manpower assignment in consulting engineering firms. *Applied Soft Computing*, *11*(1), 1183-1190.