Nana Yaw Asabere, Simonov Kusi-Sarpong / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 2, Issue 6, November- December 2012, pp.1108-1123

Mves: A Mobile Vehicle Expert System for the Automobile Industry

Nana Yaw Asabere*, Simonov Kusi-Sarpong**
*(School of Software Technology, Dalian University of Technology, Dalian, Liaoning Province, P.R. China)
**(School of Management and Economics, Dalian University of Technology, Dalian, Liaoning Province, P.R. China)

ABSTRACT

Vehicles used in our daily lives are no more considered as a luxury but a necessity. Vehicles are very helpful in our movement, logistics and transport activities. Vehicles are normally fault-prone and require efficient automobile engineering services to repair or maintain such faults. The characteristic mobility of vehicles allows them to develop faults anywhere and anytime and in some of these circumstances it is very difficult to seek the services of an auto mechanic at a vehicle fault site. Through mobile and wireless technologies, we propose mVES – a Mobile Vehicle Expert System for vehicle troubleshooting through a driver's mobile device. The research focus involved in the paper are broadly divided into two classes: (i) how to deal with an issue of a vehicle that is giving problems of sparking/starting the engine and (ii) how to deal with the problems of cooling systems of vehicles. With the efficient and effective mVES proposed in this paper, vehicle owners and drivers can diagnose their vehicle faults and problems with ease anytime and anywhere through the initial diagnosis and further advice of the proposed Expert System. The knowledge-base collected for the mVES proposed in this paper consists of a collection of knowledge from automobile/mechanical engineer experts and a website and constitutes a 15 Rule-Based procedure/strategy.

Keywords: Automobile, Driver, Engineer, Expert System, Fault, Mechanical, Mobile, mVES, Vehicle

I. INTRODUCTION

Identification and detection of vehicular faults is not easy for inexperienced mechanical engineer or driver because a lot of knowledge and expertise is required for such fault identifications and detections. Therefore, most drivers and vehicle owners depend extremely on expert mechanical engineer for vehicles fault diagnosis. Vehicles comprise of cars, buses, vans etc. and they are all fault-prone due to their machine and continuous usage nature. Of course the subject of thermodynamics has proven beyond all reasonable doubt that, there is currently no such machine that can work continuously without taking energy from outside. Vehicles are nowadays used in a variety of activities by different walks of life and as such are not considered a luxury but rather a necessity. Individuals use vehicles to go to work and firms use vehicles for their transport and logistics activities. Individuals who cannot afford a vehicle such as a car usually employ the services of public transport buses for travelling purposes. As a result of such examples and scenarios, it can be realized that all types of vehicles have their individual uses and are necessary for our daily lives depending on our particular activities.

When there is a problem or a fault with a vehicle, drivers or vehicle owners normally call in for the services of mechanical engineers/automobile engineers for help. In cases where the diagnosed fault of the vehicle is of a high
level and severity, it would be sent to an automobile shop for repairs.

It would have been appropriate if most vehicle owners were exposed to knowledge about vehicle components, how each component works, and how small problems could be solved. This is however impossible because some vehicular problems require technical knowledge to analyze and understand the problems. The technical knowledge and problem solving of vehicles is usually studied by mechanical and automobile engineers. Therefore if a vehicle owner or driver is an auto-mechanic then it becomes easier for him or her to apply a preliminary action or repair it immediately themselves in uncertain situations [1]. In a situation where the vehicle owner or driver is not an auto-mechanic, there should be systems in place to help diagnose and solve vehicle problems. In such cases, the vehicle owner or driver may diagnose a problem wrongly and it may cause more severe problems to their vehicle. Also, in uncertain situations, vehicle owners and drivers need to cope with the unexpected problems as fast as possible. Vehicle fault detection and identification is not easy for inexperienced mechanic or driver because it requires a lot of knowledge for finding the fault. Therefore, they extremely depend on expert mechanic. For example, detection of fault diagnostics and repairs of a Bus is likely to be different since their mechanical parts are different in size, portability; durability etc. Dependence of the

expert can be minimized if its expertise can be documented into a computer system [1][2]. With rapid advances and proliferations in mobile devices such as Personal Digital Assistants, Smartphones and Mobile phones [3][4], an expert system, which is a computer software program used to solve problems, coupled with mobility and mobile devices will help vehicle owners detect faults and pre-diagnosis of vehicle faults. An expert System which is a branch of Artificial Intelligence (AI) is a program that behaves like an expert in some, usually narrow, domain of application. Typical application include task such as medical diagnosis, locating equipment failures, or interesting measurement data as well as automobile applications. Expert systems have to be capable of solving problems that require expert knowledge in a particular domain. They should possess that knowledge in some form. Therefore they also called knowledge-based system [1][2].

With the expert system, the user can interact with a computer to solve a certain problem. This can occur because the expert system can store heuristic knowledge. Then the system can make inferences and arrive at a specific conclusion to give advices and explains, if necessary, the logic behind the advice. ES provide powerful and flexible means for obtaining solutions to a variety of problems that often cannot be dealt with by other, more traditional and orthodox methods. The terms expert system and knowledge-based system (KBS) are often used synonymously [5][6].

In this paper, we propose a mobile vehicle expert system (mVES) for vehicle owners and drivers. Our proposed mobile vehicle expert system (mVES) will be designed to detect faults of vehicles and produce a pre-diagnosis for vehicle owners or drivers. In cases where the vehicle owners or drivers cannot repair the vehicles themselves as a result of an acute fault, the expert system will advise for the services of a mechanic through a report of the pre-diagnosed fault. The rest of the paper is as follows: In Section 2, we elaborate and discuss our Research Objectives. In Sections 3 and 4, we discuss our Research Methodology and Problem Statement/Definition. Sections 5, 6 and 7 discuss our Research Scope, Review of Literature and Related Work respectively. We propose our Mobile Vehicle Expert System in Section 8 and present our Research Discussions and Challenges in Section 9. We finally conclude the paper in Section 10.

II. RESEARCH OBJECTIVES

The main objectives of this research paper are: To analyse how to design/develop and propose a mobile vehicle expert system for vehicle owners and drivers in order to enhance automobile services and delivery, whenever time is limited and the human expert, also known as mechanical engineer, is not available at that time of vehicle fault.

- To develop the mobile vehicle expert system as a tool for the training of inexperienced mechanical engineer and reduce the need for skilled mechanics. The repair of vehicles requires a high level of expertise. With our proposed system, an inexperienced mechanic can be guided step-by-step to find out the vehicle problem while on the move or static.
- To help mechanical engineers diagnose serious faults and repair vehicles at a faster rate through the pre-diagnosis and advice of a mobile vehicle expert system.
- To help improve knowledge of vehicle owners and drivers in diagnosing the problem of vehicle that, which will in turn reduce the level of problem severity and costs of vehicle maintenance.
- Prior knowledge in relation to vehicle problems can be used to get vehicle owners and drivers well-prepared to face such problems when they occur.

III. RESEARCH METHODOLOGY

A review of relevant literature in accordance to the objectives of this paper were explored and adopted in order to solicit the right information needed for the analysis. In accordance to the goals of this research/project, the design-based research methodology was employed to carry out this research. This is because design-based research is a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development and implementation based on collaboration among researchers and practitioners in real-world settings and leading to contextually-sensitive design principles and theories [7]. Design research was developed as a way to carry out formative research to test and refine educational designs based on principles derived from prior research. Consistent with the design research framework, this research will be carried out in the following five steps:

- *Awareness of the Problem(s)*: Identify the problem(s) by analyzing the deficiencies of the existing systems and describe how to make improvements.
- *Suggestion:* Review the related literature and previous research. Describe how the system can be designed and implemented with feasible, optimized solutions.
- *Development:* Develop and implement the proposed application(s)/system(s) according to the suggested solutions.
- *Evaluation:* Evaluate and experiment the partially or fully successful

implementations according to the functional specification.

- *Conclusion:* Discuss and draw conclusions based upon findings in the process of system design as well as the evaluations.

Figure 1, below shows Design-Based Research Phases according to [8].

We also reviewed steps that must be taken to develop an expert system. The steps are enumerated below [11]:

- Define the problem
- Evaluate alternative solutions
- Verify and expert system solution
- Estimate the payoff
- Choose an expert system tool
- Perform the knowledge engineering
- Build the knowledge base
- Develop the software
- Test and validate the system
- Maintain the system

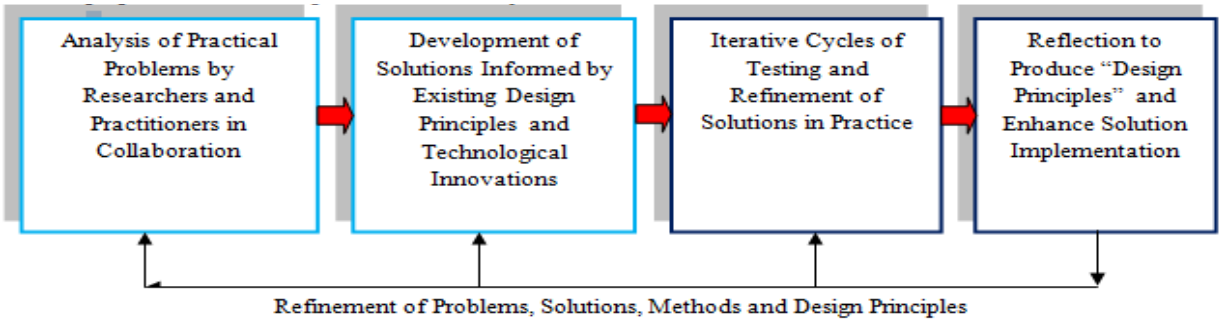

Fig. 1: Design-Based Research Phases

IV. Problem Statement/Definition

When a vehicle develops a fault, mechanical/automobile engineers are usually employed to repair/solve the vehicle fault in question. The gravity of the vehicle fault may at times be minor and not so serious to seek help from an automobile/mechanical engineer.

The automobile/mechanical engineer may be too far away from the vehicle fault site or the vehicle owner or driver may also be in a hurry to arrive at his/her destination. Therefore vehicle owners and drivers need systems that can help them to have instant solutions, especially when the gravity of the vehicle fault is minor and not so serious to require help from an engineer. We believe that the use of a mobile vehicle expert system can be beneficial in such situations through giving temporary and instance guides to vehicle owners and drivers anytime and anywhere. We also note that, not all mechanical automobile/mechanical engineers have the required expertise to solve vehicle faults. An inexperienced mechanic may wrongly diagnose the fault of a vehicle, which can easily cause the loss of customer and income of an auto mechanic repair shop. If an auto mechanic repair shop makes a wrong diagnosis for a faulty vehicle of a customer, the customer in question will be reluctant to ever come back to the repair shop with his vehicle. There is a saying that "experience is the best teacher". Therefore an inexperienced automobile/mechanical engineer needs to be trained by an expert in the same field. Training of an inexperienced automobile/mechanical engineer to acquire the right skill set and understands all vehicle fault matters and possible diagnosis takes long period of time. The time a skilled automobile/mechanical engineer needs to train an unskilled/new automobile/mechanical engineer may be limited because of other vehicles that need rapid responses and attention. Furthermore, vehicle owners and drivers waste appropriate time having to always send their vehicle to an auto mechanic repair shop to check a trivial problem which could have been repaired by themselves through the advice of a mobile vehicle expert system which has a knowledge base of experienced human automobile/mechanical engineers. If there are a lot of vehicle seeking repair attention in the auto mechanic shop, vehicle owners and drivers are likely to face high costs of vehicle maintenance and long waiting time of repair processes. Many vehicle owners don't know how to check minor faults of their vehicles in order to keep them in a good and everlasting condition. A mobile vehicle expert system that is designed to diagnose and advice on how to repair a diagnosed fault of a vehicle, can aid a vehicle owner or driver to try and repair faults that develops on the vehicle at anywhere and anytime.

V. Research Scope and Limitation

Some vehicle faults or problems are major and serious to the extent that they cannot be solved by vehicle owners and drivers even with the aid of an expert system. Such problems will eventually need to be attended to by an experienced automobile/mechanical engineer. The mobile vehicle expert system can advise the automobile/mechanical engineer in such cases

through a procedure on how to repair such faults and problems. We therefore limit our research focus to minor vehicle faults and problems. These faults and problems can be broadly divided into two classes: (i) how to deal with an issue of a vehicle that is giving problems of sparking/starting the engine and (ii) how to solve the problem of a vehicle's cooling system.

VI. REVIEW OF THE LITERATURE

A. Artificial Intelligence (AI) and Expert Systems

Artificial intelligence (AI) is the intelligence of machines and the branch of computer science that aims to represent human expertise through computers. Textbooks define the AI field as "the study and design of intelligent agents," where an intelligent agent is a system that perceives its environment and takes actions that maximize its chances of success [9].

The Expert System is a kind of computer program which can solve some difficult problems using specialist's lever and competence in some areas. The structure of Expert Systems are various according to different technologies.

Expert systems involves the study and design of systems or computer systems that represents, behaves and reasons with expert knowledge in some specialist subject with a view to solving problems or giving advice in areas where human expertise is falling short [10]. Expert systems are a contemporary type of software that is making computers more useful than ever before. An Expert system is a type of Artificial Intelligence (AI) that embodies the knowledge of one or more experts.

Figure 2 [26], shows the basic components of an expert system.

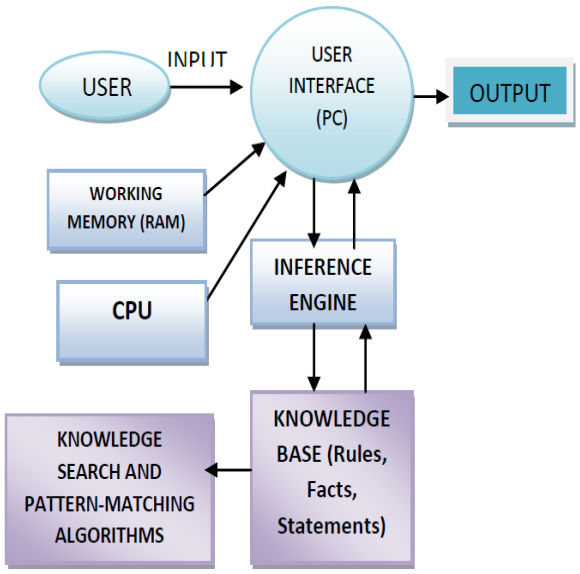

Fig. 2: Expert System

According to [9], the advantages of AI- Expert Systems are classified below:

- *Reproducibility* - Many copies of an expert system can be made, but training new human experts is time consuming and expensive.
- *Permanence* - Expert systems do not forget, but human experts may.
- *Consistency* - With expert systems similar transactions handled in the same way. The system will make comparable recommendations for like situations. Humans are influenced by recently effects (most recent information having a disproportionate impact on judgment) primacy effects (early information dominates the judgment).
- *Efficiency* - Expert systems can increase throughput and decrease personnel costs. Although expert systems are expensive to build and maintain, they are inexpensive to operate. Development and maintenance costs can be spread over many users. The overall cost can be quite reasonable when compared to expensive and scarce human experts.
- *Completeness* - An expert system can review all the transactions, a human expert can only review a sample.
- *Consistency of Decision Making*
- *Achieve Expertise*
- *Breadth* - The knowledge of multiple human experts can be combined to give a system more breadth that a single person is likely to achieve.
- *Documentation* - An expert system can provide permanent documentation of the decision process.
- *Timeliness* - Fraud and/or errors can be prevented. Information is available sooner for decision making.
- *Differentiation* - In some cases, an expert system can differentiate a learning material from other materials.

1) Science and Engineering Expert Systems

For many years, computers have aided the technical communities' research and development efforts by solving tough mathematics problems, analyzing data accumulated in tests and experiments and verifying new designs through simulation. Scientists and engineers are discovering that expert systems can greatly speed up and simplify research and development activities [11].

Nowadays, expert systems are giving workers even more computing power. Engineers are using knowledge-based Computer-Aided Design (CAD) systems to create new products. Doctors use expert systems to diagnose and treat patients with illness [11]. Scientists, engineers and technicians are creating expert systems that help them diagnose

problems in complex systems. The number of potential applications is enormous and tremendous [11].

A major category of expert systems are technical equipment diagnostics. These major systems are designed to help individuals troubleshoot and repair complex problems. Provided with a set of symptoms and observations, the system can logically reason through the problem and suggest possible causes and solutions. Like most other expert systems, troubleshooting expert systems improve productivity and save time and money [11]. They enable a technician or field service engineer to diagnose the problem and make the repair faster, putting defective equipment back on track faster. Since troubleshooting expert systems are difficult and expensive to develop, most of them are used to large, complex and expensive equipment or where large computer and telephone systems and data communication networks. The military also use expert systems to help correct faults inside major weapon systems. For example, the Navy uses expert systems to help locate troubles in radar systems. The larger and more complex the system, the more suitable it is for troubleshooting by an expert system [11].

Automobile Manufacturers are currently discovering that diagnostic expert systems can greatly facilitate both the manufacturer and servicing of automobiles. For example General Motors (GM) in the USA uses expert systems to help diagnose and repair electrical systems and the onboard computer now used in most new vehicles. Electrical systems with vehicles are complex and complicated. Spotting such problems is very difficult. An automobile expert system simplifies and speeds up the process. Many of these expert systems run on a computer that is connected to the vehicle's electrical system. This enables the system to read signals from the vehicle's computer in order to determine the current status [11].

Another automobile company, Ford, uses an expert system to help diagnose machine tool problems and problems on manufacturing tools such as robots. When such a machine or tool malfunctions, it can halt the production. Rapid troubleshooting and repair is very important. An expert system can help keep the production line rolling [11].

B. Mobile Computing and Mobile Services

1) Mobility

In this section we review some general facts and definitions about mobile services. Mobile information systems and in particular can be characterized by positioning them along three fundamental dimensions: *user mobility*, *device portability* and *wireless connectivity* [12].

- **User Mobility** refers to the fact that the user can access a mobile information system in different locations. For instance vehicle owner or driver travelling from Accra to Tarkwa in Ghana or Beijing to Dalian in China, can use his/her mobile device to access a vehicle expert system to and decide on what to do in case of a vehicle fault based on the advice and diagnosis of the expert system that is connected to the vehicle. In this example, the user is mobile; he can access the same vehicle expert system everywhere, for instance, before or during the travel, and by means of several kinds of devices with his mobile phone device. A true mobile information system should be designed in such a way that this user mobility is supported and exploited, i.e., by assigning to him a unique logical application session, so even if the system is accessed with different devices and in different usage contexts the user will get coherent replies that take into account the previous user/system interactions [12][13].

- **Device Portability** refers to the fact that the device used to access the information system is mobile. For instance a user may access the mobile vehicle expert system with a laptop or a smart phone, or a Personal Digital Assistant (PDA). These portable devices can move together with the user and can deliver the solutions of vehicle faults through the expert system. Device portability is the dimension that has been mainly studied in previous researches, because of the impact of the physical characteristics of the mobile devices, i.e., limited screen size, limited computation power and data storage, on the human/computer interaction [3][5][12][13].

- **Wireless Connectivity** refers to the fact that the device used to access the mobile vehicle expert system is networked by means of a wireless technology such as Wi-Fi, or UMTS, or Bluetooth. The network is used to access some components of the mobile vehicle expert system that are not residing on the device, and without the need of any wire. Essentially, this is probably the most important technological development, which really caused the mobile revolution, but it has not been extensively exploited in the expert system literature. In fact a wireless connectivity, in addition to adding the convenience of providing the standard networking services without the need of a wire, can open new peer to peer connection scenarios via ad hoc networking that have not been extensively exploited yet [12][13].

2) Mobile Services

M-Commerce or M-Business have been classically defined as "any business conducted over wireless telecommunications network" [14]. In this paper we want to address the pragmatic aspects of the mobility scenario and consider technology as a tool for implementing useful services. Therefore we would simply define Mobile Services as information services for mobile users, hence emphasizing the mobility dimension rather than the wireless aspect. There are several drivers for the development and diffusion of mobile services. The wide availability and convenience of the wireless communication technologies and wireless devices is just one motivation [13]. According to Reuters, in June 2007 cited by [13], the total number of cellular connections in the world reached 3.25 billion. This means that half of the world population has a mobile phone, whereas the worldwide number of PC in use is estimated to be around 1 billion. Wireless communication technologies are improving in terms of price/performance and quality (e.g. bandwidth). Consider for instance the wide diffusion of free Wi-Fi connectivity in several African and Asian cities, or the availability of flat rates data communication services over 3G networks. These technologies support effective bandwidth of some megabits, so for instance making possible and convenient streaming audio and video [13].

Mobile communication network operators and the manufacturers of mobile phones are pushing (advertising) new technologies, products and services to the customers [15][16]. This push is particularly effective on the youth; they represent a key target market for the mobile industry. Their understanding and utilization of mobile technology and the Internet is fundamentally different from that of their parents, e.g., with respect to social and privacy issues related to mobile services [17]. Meeting the demands of the youth will be a key for the success for many companies over the next years [13].

Another important factor determining the diffusion of mobile services is the increased number of workers that are mobile most of their time. Salespersons are typical and well known examples of mobile workers, but we can also mention: field service workers, such as journalists, equipment maintenance operators, or those dealing with transportation and delivery of goods. All these workers are exploiting several kinds of mobile services [13]. Mobile services have been therefore developed in several application areas: sales force automation; field force automation; warehouse and stock management; asset management; wireless operations; fleet management; customer relationships; mobile and wireless office; machine-to-machine [13][18].

3) Mobile and Wireless Communication Technologies

In this section we will very briefly mention the most important mobile communication technologies that made possible the extraordinary development of mobile services. We referred to [12] for a comprehensive description of these technologies. For the aim of this paper, the two most important technological areas are wireless communications and application frameworks for mobile services. Wireless communication technologies can be classified according to the type of supported networks. A Personal Area Network (PAN) is a Computer Network (CN) used for communication among computer devices (including telephones and PDAs) close to one person, in the range of some meters. The leading technologies for such networks are: Infrared and Bluetooth. A Local Area Network (LAN) is a CN covering a small geographic area, like a home, an office, or a group of buildings. The leading communication technology for these networks is Wireless Fidelity (Wi-Fi). A Metropolitan Area Networks (MAN) is a large CN usually spanning a city, and the typical technology used in these CNs is Wireless Interoperability for Microwave Access (WiMAX). Finally Wide Area Network (WAN) is a CN that covers a broad area, e.g., cross metropolitan, regional, or national boundaries, and it is typically implemented with: Universal Mobile Telecommunications Service (UMTS), High-Speed Downlink Packet Access (HSDPA), Enhanced Data rates for GSM Evolution (EDGE), General Packet Radio Service (GPRS) and Global System for Mobile Communications (GSM) [12][13]. In terms of data speed an efficient service, mobile technologies have evolved from First Generation (1G) through to Forth Generation (4G) i.e. 1G, 2G, 3G and 4G. 4G is the highest generation in terms of data speed and efficient mobile services such as multimedia [19].

With respect to the application frameworks, the leading solutions for developing mobile services are: Wireless Access Protocol (WAP), Java 2 Micro Edition, Windows Embedded Compact (CE) .NET with Embedded Visual C++ 4.0, and now iPhone and Android Software Development Kit (SDK). Mobile Internet requires special application frameworks because the main Internet protocol, i.e., Hypertext Transfer Protocol (HTTP) and the Hypertext Markup Language (HTML) have not been designed for mobile applications and mobile devices. Internet operations involved with mobile devices and mobile applications may not be easily supported by a wireless communication network with limited bandwidth and without TCP/IP support. For these reasons, the WAP was designed to deliver Internet content, such as standard HTML pages, and enhanced services to mobile devices and users (mobile phones, Smartphones, PDAs):

independently from wireless network standards, and with protocols open for everyone to participate [12][13].

4) Mobile Devices

Currently there are plenty of mobile devices, and many new types are introduced in the market every day. It is not easy to make a classification or simply to illustrate the main classes of devices [13]. The mobile devices available today are multi-functional and robust. The story of mobile devices is no longer solely about the way they are carried. Mobile devices whether they are mobile phones, Smartphones, i-Pads, or similar "always-connected" devices are doorways to the content and social tapestries of the network connectivity, and they function or work with just a touch *(Ericsson-Jamaica, 2012)* [20]. It is out of our scope to provide here a full description of this subject but we want to review some examples of mobile devices that can be used in developing advanced information search applications and mobile vehicle expert system. For an extensive description and classification of mobile devices, further reference and reading can be obtained from [21]. For mobile the mobile vehicle expert system, we will focus here on four classes of devices: sensor and radio frequency identification devices, mobile phones, smartphones and PDAs. We will briefly describe four types of mobile devices.

- **Sensor and Radio Frequency Identification (RFID)**: These are very simple wireless devices devoted to accomplish a few simple functions [12]. Their exploitation in expert systems is still at an early stage, but there is a good potential for their application. Sensors can detect various vehicle faults and display such faults or abnormalities on the speedometer area of the dashboard. For instance, sensors in a vehicle determine when the oil in the engine has reduced from its normal level or when the hand break in the vehicle hasn't been released by the vehicle owner or driver. In the mobile vehicle expert system, the mobile device can be connected to sensors in order to aid drivers to solve vehicle faults/problems in case they occur. A RFID reader can also be connected to a PDA or a mobile phone and can detect many different tags located in the same general area [22].
- **Mobile Phones**: The largest categories of devices for mobile learning are mobile phones. Mobile phones (also called cell phones) work by connecting through radio signals to special base stations that are linked in a cellular network. As a user moves from one cell area to another, there is a handoff (network service/connection) from one base station to the next. Sometimes the handoff loses a signal, especially in locations such as tunnels and lifts [23].
- **Personal Digital Assistants (PDAs)**: Personal digital assistants (PDAs), sometimes referred to as palmtop computers, are mobile devices with personal organization software, multimedia and office productivity functionality in a very small and portable package [23].
- **Smartphones:** As mobile phones became smaller, they also took on more features and functions. Paging devices (Pagers) or "beepers," popular in the 1980s, became incorporated into mobile phones such as the BlackBerry from the Canadian company, Research in Motion (RIM). Many phones also developed personal organizing features such as those found in many PDAs [23]. Gradually, a new type of phone known as a "Smartphone" took shape. Current Smartphones have taken on some of the functionality of laptop computers, allowing access to e-mail, documents, and Microsoft Office productivity software. Smartphones usually have a miniature QWERTY keyboard, just like a PCs virtual keyboard on a touch screen. Smartphones are currently seen as being one of the most suitable platforms for mobile learning purposes [23].

C. Importance of Information and Communication Technology in the Automobile Industry and How Innovative ICT Promotes Automobile Industry Growth

Information and Communication Technology (ICT) can very well help the automotive industry to meet the current challenges and provide a superior product and services to consumers. Today ICT is not only playing a supportive role but has become an integral part of the product and virtually the backbone of the industry. The recent launch of the Google car is a clear testimony to this [24]. The focus of many companies in both ICT and auto industries is on the 3Es factors – *emerging markets*, *emerging technology* and *environmental concerns* which are guiding investments and growth in both industries [24].

Innovation in the ICT industry is far more rapid. Automobile manufacturers are investing heavily in Research and Development projects leveraging these emerging technologies. Today, the ICT content in an automotive is over 14 per cent, which is expected to go up to 21 per cent in 2015 [24]. There are about 10 million lines of code which drives a luxury automobile. In 1970 it was just 100 lines. Over the 80 per cent of innovation, Research and Development are related to electronics and embedded systems. The role and collaboration of ICT companies is very significant in all such innovations. Besides ICT being integral part of an automobile, innovation in ICT enables the industry to be more efficient in

designing, manufacturing, distributing and servicing its products worldwide. Original Equipment Manufacturers (OEMs) are leveraging the ICT platform to reduce the product development cycle time with features such as target design, cost and time. The cycle time is being crashed from six years to almost less than 24 months now [24].

An equally important focus of the automobile industry globally is on green cars and sustainable mobility. From hybrids to hydrogen cells, the world's leading OEMs are working vigorously to increase their production of 'green cars' [24].

New business models such as car sharing and integrated urban mobility as well as electric vehicles will create new business opportunities. The connected vehicle initiative in the industry will further facilitate sustainable mobility. ICT plays a crucial role in connected navigation, offering services like eco driving, dynamic routing, real time traffic information and other services such as mobile vehicle expert systems which is the focus of this paper. These are crucial for an effective integrated mobility solution [24].

VII. Related Work

Car fault identification is not easy for inexperienced mechanical engineer or driver because it is needs a lot of knowledge for finding the fault. Therefore, they extremely depend on expert mechanical engineer. The study in [1], developed an electronic learning (e-learning) system for car faulty diagnosis. The e-learning system for car faulty diagnosis in [1] was developed by using 19 rule-based of knowledge-base collected from mechanical engineering experts, specialized books, and from different car websites. In [1], three knowledge bases comprising, car start problem, break problem, and cooling system problem were created after compiling enough information for each problem using Visual Basic and Microsoft Access. The system in [1] was designed to meet user's needs in terms of ease of use and understandability and convenience that were the most necessary factors that attract users to use the system. Furthermore, the system in [1] indicated that an expert system will be practical and can be useful in providing consistent car problem detection. The study in [1] concluded in that e-learning for car faulty diagnosis is helpful although it might not give a complete guide and help as a human expert such as a mechanical engineer will do, but at least the e-learning for car faulty diagnosis can give a temporary assistance to those who are in urgent need of an instance help.

The study in [2] stresses on the fact that maintaining a car is very expensive and it is also difficult to get a good mechanic. It will be helpful if most car owners and drivers had some knowledge on automobile. The study in [2] discusses how to rectify some of the problems involved in car faults and the need to consult a mechanical engineer only when the fault/problem of the car is major/serious. The study in [2], therefore developed an expert system for car troubleshooting. The problems in [2] were broadly divided into two classes, namely: car can't be started and car breaks down. These major classes in [2] were further divided to identify the basic part, which creates the problem. The remedy is given if the problem is simple. If the problem is complex, the system in [2] will provide the causes.

VIII. Proposed Mobile Vehicle Expert System (MVES)

A. User Requirements for mVES

Users who will use mVES are most likely to be vehicle owner or drivers with less experience in automobile/mechanical engineering. Users can be in different categories ranging from individual students and workers. Vehicle owners and drivers who use mVES will have the opportunity to gain knowledge on how to maintain their vehicle in order to keep it in good condition. Inexperienced automobile/mechanical engineers can use mVES to gain more knowledge and improve their working performance. Experienced automobile/mechanical engineers can also use mVES to help them make better and faster decisions, when a recommendation is sought from them.

B. System Requirements for mVES

We propose to develop a mVES, which will involve all vehicle owners or drivers equipped with a Sensor-Based and connected mobile device (Mobile Phone, Smartphone, or PDA). The mobile devices used for mVES will be current and should avoid known challenges of mobile devices such as limited screen, low battery, low processing power, reduced input capabilities etc. Due to unrestricted mobility of users, we propose WAN connected to a dedicated server with internet access (HHTP and HTML) and 3G communication technologies (UMTS) that will offer to vehicle owners or drivers a wide range of advanced services:

C. Designing of the Required Knowledge-Base for mVES

The knowledge of the system is collected from mechanical engineering experts and from the automobile website, AA1CAR.com [25]. The main knowledge base involved in our proposed design was vehicle start problem and cooling system problem. We used these knowledge bases with reference from table 1 to develop a 15 rule-based as described below on the next page.

Table I: Starting Fault/Problem and Solutions of Vehicles

SYMPTOM	POSSIBLE CAUSE	ACTION NEEDED
Engine will not crank	• Dead battery • Melted fusible link • Loose Connections • Faulty ignition switch • Faulty magnetic switch, relay, neutral start switch or clutch switch • Mechanical problem in engine • Problem in theft deterrent system	• Check battery state-of-charge • Replace fusible link • Clean and tighten connections • Check switch operation; replace as needed • Check and replace as needed • Check engine • Check service manual for system tests
Engine cranks too slowly to start	• Weak battery • Loose or corroded connections • Faulty starter motor • Mechanical problems with engine or starter	• Check battery and charge as needed • Clean and tighten connections • Test starter • Check engine and starter; replace worn out parts
Starter keeps running	• Damaged pinion or ring gear • Faulty plunger in magnetic switch • Faulty ignition switch or control circuit • Binding ignition key	• Checks gears for wear or damage • Test starter pull-in and hold-in coils • Check switch and circuit components • Check key for damage
Starter spins, but engine will not crank	• Faulty over-running clutch • Damaged or worn pinion gear or ring gear	• Check over-running clutch for proper operation • Check gears for damage and wear; replace as needed
Starter does not engage/disengage properly	• Faulty magnetic switch • Damaged or worn pinion gear or ring gear	• Bench test starter • Check gears for damage and wear; replace as needed

Source: Toyota, Retrieved From: *http://www.aa1car.com/library/1999/cm119948.htm*

Fig. 3: Mobile Vehicle Expert System (mVES)

Fig. 4: Add New Customer (Vehicle Owner or Driver) Window 1

- **Rule 1**: **IF** vehicle owner or driver turns the key ignition to start the vehicle **AND** engine doesn't crank **THEN** clean and tighten vehicle battery terminals connections and check state of vehicle battery.
- **Rule 2**: **IF** vehicle battery terminal connections and battery are checked and the vehicle owner or driver turns the key to ignite to restart the vehicle **AND** /vehicle still doesn't crank **THEN** check if vehicle has enough fuel/gas or oil.
- **Rule 3**: **IF** vehicle battery terminal connections are cleaned and tightened, there is enough fuel/gas **AND** the engine still doesn't crank **THEN** check switching operation.
- **Rule 4**: **IF** Rule 1, Rule 2 **AND** Rule 3, don't provide any solution to vehicle engine not cranking **THEN** vehicle fault/problem might be major and likely to be electrical problem. Seek the services of an experienced Mechanical/Automobile Engineer with report from Rule 1 and Rule 2 (Recommended).
- **Rule 5**: **IF** vehicle owner or driver turns the key to try to start the vehicle **AND** the engine is cranking slowly resulting in the vehicle failing to spark **THEN** vehicle battery is weak and needs to be checked and charged.
- **Rule 6**: After checking and charging vehicle battery, **IF** vehicle owner or driver turns the key to try to restart the vehicle **AND** the engine is still cranking slowly resulting in the vehicle failing to spark **THEN** vehicle battery is weak and needs to be replaced/changed and starter needs to be tested.
- **Rule 7**: **IF** Rule 5 **AND** Rule 6 don't provide any solution to the vehicle engine cranking slowly, **THEN** vehicle problem might be related to starter. Seek the services of an experienced

Mechanical/Automobile Engineer with report from Rule 6 and Rule7 (Recommended).

- **Rule 8**: **IF** vehicle owner moves the vehicle **AND** vehicle is shaking/jerking while in motion **THEN** vehicle has problem with spark plugs in the engine and needs to be checked.
- **Rule 9**: **IF** vehicle owner moves the vehicle **AND** vehicle is still shaking/jerking while in motion after spark plugs in engine have to be checked **THEN** vehicle has fault/problem contact set or distributor cap.
- **Rule 10**: **IF** Rule 8 **AND** Rule 9 don't provide any solution to vehicle shaking/jerking **THEN** vehicle fault is likely to be major. Seek the services of an experienced Mechanical/Automobile Engineer with report from Rule 8 and Rule 9 (Recommended).
- **Rule 11**: **IF** vehicle owner moves the vehicle **AND** the vehicle engine temperature is increasing while in motion **THEN** check water level in radiator.
- **Rule 12**: **IF** after checking/correcting the water level in radiator, the vehicle engine temperature is still high vehicle **AND** engine is overheating **THEN** stop vehicle and restart after 20-30 minutes.
- **Rule 13**: **IF** Rule 11 and 12 don't provide any solution to vehicle cooling system **AND** vehicle engine temperature is still high **THEN** fault is likely to be major. Seek the services of an experienced Mechanical/Automobile Engineer with report from Rule 11 and Rule 12 (Recommended).
- **Rule 14**: **IF** vehicle owner turns off engine and headlights **AND** headlights don't go off **THEN** there is an electrical problem with headlights and battery will become weaker, so battery terminals should be removed.
- **Rule 15**: **IF** vehicle owner fixes the battery terminals back, switches off headlights **AND** headlights still don't go off **THEN** fault is likely to be major. Seek the services of an experienced Mechanical/Automobile Engineer with report from Rule 14 (Recommended).

The front-end of our proposed mVES are shown from figures 3-10. Figure 4 (Add New Customer) allows new customers to add/subscribe themselves as to the system and provide relevant information such as Confidential ID, Name, Address, Mobile Phone Number, E-mail and Type of Car.

After the user inputs these information, he/she clicks/presses "Add" and then "Start Interaction with mVES to introduce figures 5 (Add New Customer Window 2) and 6 (Confirm and Login). In figure 3 (mVES), existing users click on the second option (Existing Customer Login) to proceed with Confirm and Login as shown in Figure 6. Figure 5 allows New Customers to recheck their data/information they previously provided in figure 4. In figure 6, mVES users confirm and login through their confidential ID and Name. When mVES users click/press "Confirm and Login" after inputting confidential ID and Name, figure 7 which allows users to interact with the mVES is introduced.

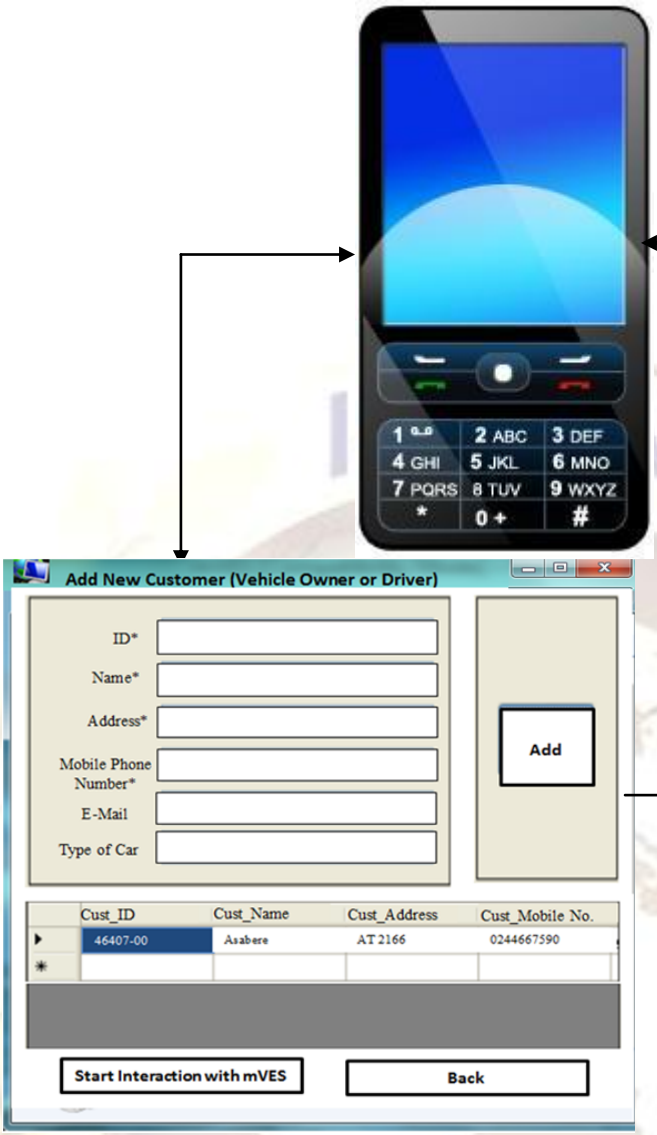

Fig. 5: Add New Customer (Vehicle Owner or Driver) Window 2

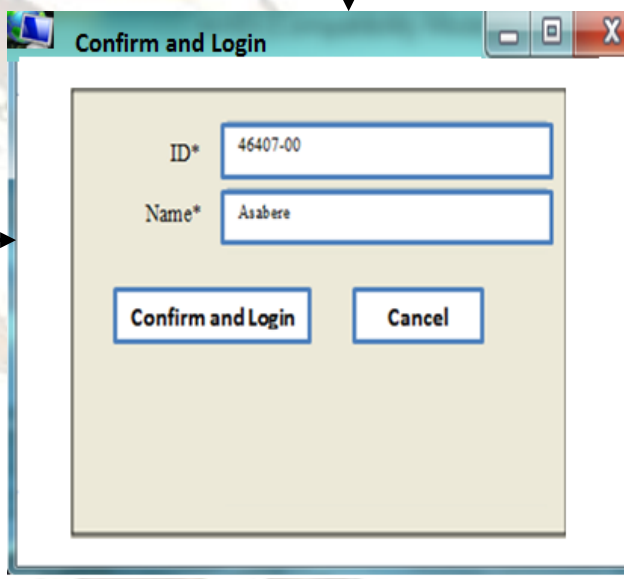

Fig. 6: Confirm and Login Window

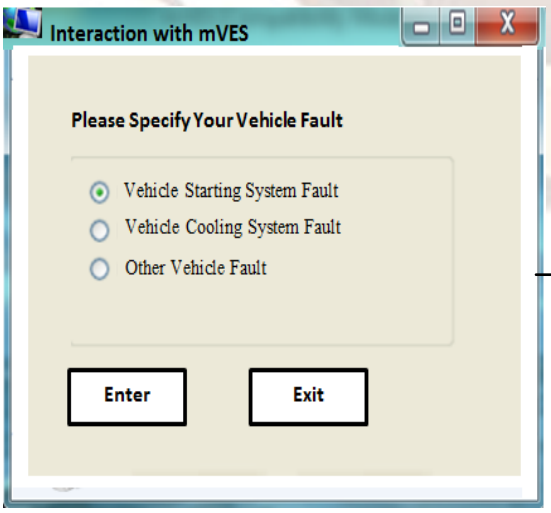

Fig. 7: Interaction with mVES Window

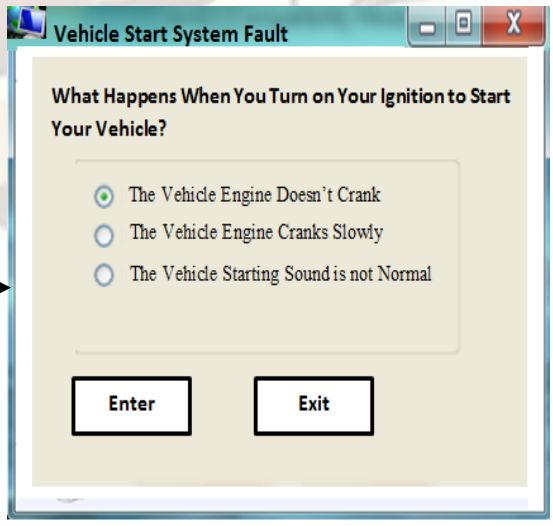

Fig. 8: Vehicle Start System Fault Window

In figure 7 (Interaction with mVES), the mVES user is asked to specify his/her vehicle fault and chooses "Vehicle Start System Fault" and then click/presses Enter. The next window introduced after this is figure 8 (Vehicle System Fault) which queries "What Happens When You Turn on Your Ignition to Start Your Vehicle"? The mVES user chooses "Vehicle Engine Doesn't Crank" and clicks/presses Enter. The next window figure 9 (Vehicle Fault Diagnosis) depicts diagnoses and recommendations with reference to the knowledge-base for the Vehicle Engine Doesn't Crank Fault previously chosen by the user with an option to sends a report to seek the services of an experienced automobile engineer or to save if problem is resolved. To stop using mVES, users have to click/press Exit in figure 9, proceed to figure 10 and click/press the available options i.e. Yes, No or Cancel.

Fig. 9: Vehicle Fault Diagnosis Window

Fig. 10: Exit mVES Window

VIIII. RESEARCH DISCUSSIONS AND CHALLENGES

During implementation, vehicle owners or drivers who are not literate in using a mobile device to the extent of interacting with a mVES interface have to be taught how to use the mobile device for such activities. Vehicle owners or drivers who are very conversant with mobile device usage in terms of interface interactivity will also have to be trained on the procedures of how to use a mVES. The proposed system in this paper is purely technological inclined and would require technical knowhow and hands on skills of using mobile devices efficiently. Since the proposed system is featured with mobile technology, interaction with the mVES can occur anywhere and at any time. Mobile devices belonging to patients and experienced automobile/mechanical engineers in which reports would have to be sent to in case the system suggests such recommendations, should always be in and "ON" state. The proposed system would fail especially in terms of reports being sent to experienced automobile/mechanical engineers in real time, if the mobile device of the experienced automobile/mechanical engineers is in an "OFF" state. The use of the system by the elderly and people who are not very conversant with enhanced mobile device usage is a challenge and limitation of the proposed system in this research paper.

Successful implementation of the proposed system in this paper requires effective and strict strategies of automobile industries on vehicle owners or drivers to comply and use the mVES through registration and subscription.

It must be emphatically stated that there are various degrees of vehicular faults, the mVES proposed in this paper in solely for minor starting and cooling system faults of vehicles which may not need the services of an experienced automobile/mechanical engineer. The proposed mVES cannot diagnose major faults of vehicles, which will require service of an automobile/mechanical engineer.

X. CONCLUSION AND RECOMMENDATION

A. Conclusion

This paper proposed a Mobile Vehicle Expert System (mVES) that can be used to solve vehicular problems of vehicle owners or drivers anytime and anywhere. Not all vehicular problems and faults will require services of an experienced automobile/mechanical engineer because vehicular faults involving starting and cooling systems may be minor and as such vehicle owners or drivers should be able to solve such problems themselves through a mVES. At any location and at any time, the proposed mVES in this paper will help vehicle owners or drivers as well as automobile/mechanical engineers improve and solve vehicular problems through the fault diagnosis and consequent advice of the expert system.

B. Recommendation

This research paper recommends that the global automobile industry should develop Mobile Vehicle Expert Systems to help and advice vehicle owners or drivers with vehicular faults and problems when they occur at any time and at any location.

REFERENCES

[1] S. Adsavakulchai, N. Ngamdumrongkiat and E. Chuchirdkiatskul "E-Learning for Car Faulty Diagnosis", *International Journal of Information and Communication Technology Research*, Vol. 1, No. 1, pp. 20-26, 2011.

[2] S. T. Deepa and S. G. Packiavathy "Expert System for Car Troubleshooting", *International Journal For Research In Science & Advanced Technologies*, Vol. 1, Iss. 1, pp. 46-49, 2012.

[3] S.J. Yong, H.Y. Lee, H.K. Yoo, H.Y. Youn and O. Song "Personalized Recommendation System Reflecting User Preference with Context-Awareness for Mobile TV", *Ninth IEEE International Symposium on Parallel and Distributed Processing with Applications Workshops*, pp. 232-237, 2011.

[4] W.Z. Khan, Y. Xiang, M.Y. Aalsalem and Q. Arshad "Mobile Phone Sensing Systems: A Survey", *IEEE Communication Surveys and Tutorials*, pp. 1-26, 2012.

[5] A. Aamodt, E. Plaza "Case-based Reasoning: Foundational Issues, Methodological Variations, and Systems Approaches". *Artificial Intelligence Communications*, *IOS Press*, Vol 7, No. 1, pp. 39-59, 1994.

[6] F. Hayes-Roth "Rule-Based Systems" *Communications of the ACM* , Vol. .28, No. 9, 1985.

[7] F. Wang and M.J. Hannafin "Design-Based Research and Technology-Enhanced Learning Environments", *Educational Technology Research and Development*, Vol. 53, No. 4, pp. 5–23, ISSN 1042–1629, 2005.

[8] T. Amiel, & T. C. Reeves "Design-Based Research and Educational Technology: Rethinking Technology and the Research Agenda", *Educational Technology & Society*, 11 (4), pp. 29–40, 2008.

[9] Jaryani, F., Sahibudin, S., Ibrahim, S., Rahman, N.A. and Daruis, R. (2011). "Intelligent Reflective E-Portfolio Framework Based on Artificial Intelligence Expert Systems Techniques",

IEEE 3rd International Conference on Computer Research and Development (ICCRD), pp. 214-216, 2011.

[10] J. Ignizio "Introduction to Expert Systems".*ISBN 0-07-909785-5*, 1991.

[11] L.E. Frenzel Jr. "Understanding Expert Systems", *First Edition, Sam's Understanding Series*, 1987.

[12] J. H. Shiller "Mobile Communications", *Addison-Wesley*, 2003.

[13] F. Ricci "Mobile Recommender Systems", *International Journal of Information Technology and Tourism*. Vol. 12, No. 3, pp. 205-231, 2011.

[14] E. Turban, J. K. Lee, D. King, J. McKay and P. Marshall " Electronic Commerce", *Prentice Hall*, 2008.

[15] R. Bulander, M.Decker, G.Schiefer and B. Kolmel 2005 "Comparison of Different Approaches for Mobile Advertising", *The Second IEEE International Workshop on Mobile Commerce and Services* (*WMCS*), pp. 174–182, 2005.

[16] R. Vatanparast "Piercing the fog of Mobile Advertising" *International Conference on the Management of Mobile Business (ICMB)*, pp. 19–19, 2007.

[17] S. S. Choi and M.-K. Choi "Consumer's Privacy Concerns and Willingness to Provide Personal Information in Location-Based Services", *The 9th International Conference on Advanced Communication Technology*, Vol. 3, pp. 2196–2199.

[18] U. Bertel´e and A. Rangone "Rapporto Mobile and Wireless Business*", Politecnico di Milano*, 2007.

[19] S. Mann "The Emergence of Mobile Devices Influencing Learning From the Viewpoint of Convergence", *Fifth IEEE International Conference on Wireless, Mobile, and Ubiquitous Technology in Education*, pp. 191-193, 2008.

[20] Mobile Manufacturer Ericsson (2012), Retrieved, 15th October 2012, from: *http://www.ericsson.com/jm/news/1430616*.

[21] S. Gansemer, U. Groner and M. Maus "Database Classification of Mobile Devices"', *4th IEEE Workshop on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications*, pp. 699–703, 2007.

[22] F. Cena, L. Console, C. Gena, A. Goy, G. Levi, S.Modeo and I.Torre "Integrating Heterogeneous Adaptation Techniques to Build a Flexible and Usable Mobile Tourist Guide", *AI Communication*, Vol. 19, No. 4, pp. 369–384, 2006.

[23] G. Woodill "The Mobile Learning Edge" Publisher: *The McGraw Hill Companies*, 2011.

[24] S. D. Subramanian "How Innovative ICT Promotes Automobile Industry Growth" *in Technology by Gopaladmin, E-Magazine*, July 2012.

[25] AA1CAR.com, Retrieved [Online] From: *http://www.aa1car.com/library/1999/cm119948.htm* on 03/11/2012.

[26] N.Y. Asabere and S.E. Enguah "Integration of Expert Systems in Mobile Learning", International Journal of Information and Communication Technology Research, Vol. 2, No. 1, pp. 55-61, 2012.

AUTHOR BIOGRAPHIES

Nana Yaw Asabere received his BSc in Computer Science from Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana in 2004 and MSc in ICT from Aalborg University, Denmark in 2010. He has eight (8) years of teaching/lecturing experience at tertiary level of education in Ghana and is currently on Lectureship Study Leave granted by Accra Polytechnic, Ghana pursuing his PhD in Computer Software Engineering at School of Software, Dalian University of Technology, Dalian, P.R China. He has a number of journal publications in International Journals. His research interests include: Artificial Intelligence (AI), Software Engineering, Expert Systems, Mobile Learning, E-learning, ICT in Education, Information Systems, Multimedia, Recommender Systems, Social Computing, Wireless/Data/Mobile Communication and Computing Technologies.

Simonov Kusi-Sarpong earned his Undergraduate University Diploma in Mine Mechanical Engineering from Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana in 2001 and MSc in Operations & Supply Chain Management from University of Liverpool, United Kingdom in 2011. Simonov is also a Chartered Member (MCIPS) of the Chartered Institute of Purchasing & Supply, United Kingdom. He has over ten (10) years mix working experience in the Supply Chain Management and Engineering

Environments as well as Construction and Mining Industries with additional couple years in Business Development Management in the Mining/Oil & Gas, Mining and Industrial with relation to Procurement Services. Simonov is self-motivated Engineering, Business Development, Logistics, Operations and Supply Chain Professional, whose objective, is to apply and utilize his ingenuity and knowledge in the field of Engineering, Business Development, Logistics, Operations and Supply Chain while working and learning with good qualities of team work and leadership to achieve greater heights. His research interest cut across Engineering, Business Development, Logistics, Operations and Supply Chain with greater focus on topics related to logistics & supply chain management processes improvements. His is currently pursuing PhD in E-Business & Logistics Management at School of Management & Economics, Dalian University of Technology, Dalian, P.R China. He has a couple of academic journal in his name