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Content

Keynote Speaker 1

Nobuyoshi Koga

A Multidisciplinary and Comprehensive Chemistry Teaching/Learning for Next Generation

Nobuyoshi Koga

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Abstract

It is recognized that the successful promotion of STEM education is continuous subject for realizing the sustainable development of the world with the aid of scientific and engineering innovations. For promoting STEM education, science education involving chemistry education should play an important role because of its multidimensional objects. When the educational objects, involving the trainings and acquisitions of scientific concepts, knowledge, methodologies, skills, logical thinking, science ethics, and so on, were sufficiently achieved as the results of highly motivated student inquiries, the teaching/learning activities in science education can be the core for linking different STEM subjects and promoting the overall STEM education. For chemistry education, many distinguished materials and phenomena applicable to introduce different chemical topics at different learning stages are available in our neighborhood. Using those instruction materials, well-organized inquiry activities for studying chemistry can be designed with different types of scientific inquiry processes. For the success of chemistry education, systematic organization of the multiplicities of the instruction materials and pedagogical designs in chemistry learning programs and curriculums appears to be one of the keys.

In this talk, a possible strategy for realizing such a multidisciplinary and comprehensive chemistry teaching/learning in K-12 level is discussed by reviewing our challenges of research based educational practices in STEM-focused schools. First, the basis for developing the next generation chemistry teaching/learning is considered on the basis of the present status and issues of chemistry education. A possible curriculum design is then proposed with an emphasis of the requirement of storylines of chemistry learning for students. A series of learning programs with different styles of inquiry-based laboratory exercises applied at different learning stages and situations construct the storyline, which closely correlates everyday chemistry learning based on content-based learning and periodically introduced inquiry-based learning. Instruction materials utilized in the learning programs can be found in elsewhere. The learning programs using household materials [1,2], minerals [3], and thermochemical phenomena [4-9] are introduced by describing the multiple faces of these instruction materials and pedagogical logics and by reviewing our educational practice in schools. The multifaceted feature of the instruction materials links length and breadth of the different learning topics in chemistry, the different subjects in science education, and further the different STEM subjects. At the end, ability being required for chemistry teachers for promoting the ideal chemistry education is discussed by introducing the know-how of pre-service and in-service teacher trainings accumulated in our Department of Science Education, Graduate School of Education, Hiroshima University.

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Keynote Speaker 2

Bhinyo Panijpan

Chemistry Education at Tertiary Levels

Bhinyo Panijpan

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Abstract

Chemical education has to keep abreast of on going research and development in chemistry in light of the omnipresence of electronic data, information, knowledge and knowhow. Curriculum or instruction, pedagogy and assessment need to be constantly modified. Frequent instructor - student interaction is necessary. Research and development by instructors are essential.

Keywords : Frequent instructor

Introduction

One prominent aspect that distinguishes this present century from the past 20th century in the omnipresence of the Internet . The Internet facilitates ever faster and wider same-time accessibility to electronic information and communication worldwide. Now people everywhere could be equal in learning about things past, present and the near future given the opportunity, the will and necessary resources. They can receive and distribute information almost instantly. The likes of Google, Wikipedia, on-line publications, electronic databases, posted lectures and animations, social media, etc. make it possible for people to intelligently learn about their world and beyond.

Thus we are no longer confined to textbooks, monographs, paper-based publications, etc. Learners and instructors can dig into the world' s treasures of good data, information, knowledge and wisdom as much as they want. Now the challenge is how to benefit the most from what is available in terms and
electronic and human resources.

In the last few decades leading chemistry research works and their applications have undergone some significant transformations. However, textbooks and materials used to teach undergraduates lack behind realities in the field more than before. The mode of instruction in the lectures and student laboratories also lacks behind. We therefore have to concentrate more on present works in chemistry that will lead to usage in the near future.

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Changes in Chemistry

For good reasons research in chemistry has recently emphasized more on biologically important problems of big molecules, biological mimic structures, applications at the sub-micron and nano levels. Synthesis of unusual and large structures has also been more and more ambitious. Novel sensors, energy converters, catalysts are intensely researched and commercial applications are made not too long after R&D. Analytical tools have also been more powerful as well as sensitive.

Gigantic biological structures and functions have become solved routinely by nuclear magnetic resonance, x-ray diffraction, mass spectrometry, Raman spectroscopy, spectrofluorometry, etc. Single molecule studies are more possible. Also atomic force microscopy is becoming more far reaching. These techniques must be taught at lower levels now.

Elements beyond the third period that used to be ignored or relegated to a few mentions in introductory courses have now become more prominent commercially and in research &development, these heavier elements used in the semiconductor and superconductor industries should be emphasized more,

Changes in Pedagogy

The above calls for big changes in pedagogy toward student-centered learning which is now more justified than before.

Since students can learn about things any time and anywhere which come with instant and ubiquitous accessibility to the internet, the emphasis now must be on their profound learning at levels not quite emphasized before, e.g., ability to compare and contrast, to analyze and synthesize, to evaluate what is being presented. Students also have to be able to work together collaboratively because the world now demand creativity and innovation. Instructors have then to be value-added agents by being interactive with students so that the latter own their knowledge by actively learn and reflect on what they acquire in class and outside class. Instructions have to be challenging and authentic so that students will carry out laboratory work more actively. Assessments of success and achievement have also be authentic as well as futuristic.

Thus curriculum has to be constantly changing to respond to the real world that our graduates have to face upon graduation and beyond in their employment. They will have to be knowledge workers, life-long learners with creativity and ability to communicate well.

New Roles for Instructors

Instructors have to move away from their conventional teaching approaches to lecture, laboratory and assessment of students' performance. They have to interact with students more so that they can assess them formatively to ensure better learning for higher numbers of students.

Instructors have to actively do research, attend seminars and conferences on chemistry. They have to work together with other instructors to find better ways to instruct, e.g., being good coaches, guides, facilitators, mentors, etc.

In addition instructors should read published work on chemical education. Better still they should carry out chemical education research and use their own works as well as others' to help in their instruction. Instructors should invent apparatuses for demonstration and electronic simulations and games to attract interest of students. The author will provide several of his published works to show that these works are possible while one pursues conventional research, publication and other duties.

Conclusion

In this fast changing world of instant accessibility to chemical information and new trends of rapid application of chemical research, instructors and learners have to interact more frequently for more profound life-long learning. Curriculum/instruction, pedagogy and assessment have to take advantage of the changes above. Instructors have keep abreast of the field by carrying out conventional research and following published chemical education research works.

Keynote Speaker 3

Kamisah Osman

Students as Digital Game Designers: Addressing the 21st Century Chemistry Education Needs in Malaysia

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Abstract

In order to meet the challenges in the global economy market of the 21st century, Malaysia needs to produce students who master both the knowledge of chemistry and 21st century skills. Chemistry is one of the important branches of science. However, chemistry is perceived as a difficult and unpopular subject due to the abstract nature of chemical concepts. The purpose of this paper is to propose an instructional approach that emphasizes simultaneously on enhancing conceptual understanding and developing the 21st century skills. Many studies have reported that digital game-based learning can provide positive impact on students‟ learning. Commercial and educational digital games have been developed for classroom integration. However, there are many obstacles to implementing the students as game consumers approach in the educational settings. One alternative approach offered by some researchers is to allow students to take on the role of game designers, developing digital games during teaching and learning process. It is believed that this approach can create a platform that allows students to deepen subject content knowledge, and practice various 21st century skills in real situations. Based on this approach, a module known as MyKimDG has been developed. This paper also demonstrate a brief lesson in MyKimDG to the teaching and learning of a specific unit in the Malaysian Chemistry Curriculum.

Keywords: chemistry learning, constructivism, constructionism, and learning through designing.

Introduction

Malaysia needs to produce students who are competent in the field of science and technology (S&T), and hence capable of generating S&T innovation to contribute to the well-being of mankind as well as to trigger the country‟s economic growth. To become competent in the field of S&T, students must be STEM (Science, Technology, Engineering and Mathematics) literate and have mastery of the 21st century skills.

STEM literate students must have master the knowledge of chemistry because knowledge of chemistry applied across most of the fields of S&T (Balaban and Klein, 2006). Indeed chemistry is often called the central science (Brown et al., 2011; Chang, 2007). According to Risch (2010), the knowledge of chemistry is the foundation for innovation, scientific literacy and most notably problem solving in connection with sustainable development. With chemistry knowledge, materials can be designed to solve various problems in everyday life. In the 21st century, chemistry will continue to play a leading role in the field of S&T and contribute towards solving the problems of human life.

Apart from knowledge, innovation in the 21st century requires a new range of skills known as 21st century skills. For example, innovation in today‟s world is driven by the formation of networks with multiple parties including experts and researchers with related interests as well as consumers and customers. The 21st century skills enable one to communicate and collaborate effectively with various parties.

In short, students who are competent in the field of S&T must master both the knowledge of chemistry and the 21stcentury skills. Therefore, chemistry education in Malaysia in the 21st century should be given simultaneously on integration of knowledge acquisition and nurturing of 21st century skills to ensure that students are equipped with knowledge, skills and values that are relevant to the current needs so that they can adapt themselves to the 21st century work and social environments.

Chemistry Education in Malaysia

In the early 1960s, students at upper secondary level learn science based on the syllabus by the Cambridge Examination Syndicate. In 1972, Modern Chemistry subject was introduced at upper secondary level. The syllabus was adapted from the Nuffield Chemistry 'O' level course.

In 1989, an indigenous form of curriculum that best suit the national context, known as the Integrated Curriculum for Secondary School (KBSM), was implemented in Malaysian secondary schools. The Malaysian Science Curriculum was developed based on the National Education Philosophy, National Science Education Philosophy and taking into consideration the vision and mission of the national and global challenges.

Chemistry is one of the elective science subjects in the Malaysian Science Curriculum offered at the upper secondary level. The Chemistry curriculum has been designed not only to provide opportunities for students to acquire chemistry knowledge and skills, develop thinking skills and thinking strategies, and to apply this knowledge and skills in everyday life, but also to inculcate in them noble values and the spirit of patriotism (Bahagian Pembangunan Kurikulum, 2012).

In line with the current global changes in the 21st century as well as the national vision and mission, Malaysia has concentrated its efforts to produce students who are equipped with the knowledge, skills, and values that need to be mastered to succeed in life and careers in the 21st century. Starting in 2011, the national curriculum is giving greater emphasis on Higher Order Thinking Skills (HOTS), and various 21st century skills such as reasoning, creativity and innovation, entrepreneurship, and information and communication technology (ICT). Thus, in teaching and learning, teachers need to emphasise the mastery of those skills together with the acquisition of knowledge and the inculcation of noble values and scientific attitudes.

Digital Games and Chemistry Learning

Chemistry is usually considered difficult. The abstract nature of many chemical concepts is one of the key factors that cause difficulty in learning chemistry. While the literature is replete with studies and papers, which investigate students‟ understanding of chemical concepts and suggest potential remedies, fewer studies focus simultaneously on enhancing conceptual understanding and developing the 21st century skills. Hence, educators should be encouraged to design innovative and effective learning strategies to enhance both conceptual understanding and 21st century skills development. In this case, a change in chemistry teaching and learning (T&L) practices is critical. This is especially more crucial when dealing with today‟s students who are „native speakers‟ (Prensky, 2001) of the digital language of computers, digital games and the internet. The T&L practices must meet the needs of these digital natives and subsequently achieve the desired aspiration.

One approach suggested by researchers to educate the digital native generation is the integration of digital games in the T&L processes as digital game is a medium favoured by students. In Malaysia, Rubijesmin (2007) showed that 92.1% of students involved in the study were familiar with digital games. After several years, Lay and Kamisah (2015) revealed that the percentage has increased to 98.8%, and 21.8% of them used at least 3 hours per day for playing digital games. Nowadays, the integration of digital games in learning or digital game-based learning (DGBL) is gaining popularity parallel with their popular reputation among students (Kamisah and Aini, 2013). Many studies have reported that DGBL can provide positive impact on students‟ learning. In general, the studies on DGBL were carried out through two approaches, namely (1) student as game consumer or player, and (2) student as game designer.

In the first approach, the students were involved in playing digital games developed by educators or commercial digital games in the market. However, there are many obstacles to implementing the student as game consumer approach. For instance, the contents of commercial digital games are inaccurate or incomplete (Van Eck, 2006) and the development of professional educational digital games is time consuming (Hwang et al., 2013). In addition, many digital game players do not play educational digital games as they do not find the game play in these games to be compelling (Pivec, 2009). This happens because educational digital games are designed by academics who do not really understand the art, science and culture of digital game design (Van Eck, 2006). As a result, the product has failed dismally as a game. Prensky (2008) also raised this issue and states „*..the students had no input into its creation, and the stuff came out cute to the adults, but boring to the kids*". According to Prensky (2008), students even told straight forwardly: „*Don't try to use our technology, you'll only look stupid*."

One alternative of DGBL approach that has been proposed by some scholars (such as Kafai, 1996; Papert, 1998; Jung and Park, 2009; Kamisah and Aini, 2013) is for students to design their own digital games. Many studies have reported that this approach provide opportunities for students to explore ideas according to their own interests (Kafai & Ching, 1996); become active participants and problem solvers, engage in social interaction by sharing their designs and helping each other, and take ownership of their own learning (Baytak & Land 2010); acquire knowledge of programming (Kafai et al., 1997); as well as develop ICT literacy to produce new things and develop new ways of thinking based on the use of ICT tools (Kafai, 2006). Digital game design activities also open the door for young digital game players to become producers of digital games (Kafai, 2006). In addition, Vos, van der Meijden and Denessen (2011) has reported that this approach is a better way to increase student motivation and deep learning compared to the student as game consumer approach. In Malaysia, Yusoff (2013) also found that this approach can enhance students' knowledge in addition to creating a fun environment. In short, the student as game designer approach can enhance deep learning and provide a platform for students to develop the 21st century skills.

Therefore, we have initiated an innovation approach which involves students as digital game designers while learning chemistry to deepen their understanding in chemical concepts,

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and practice various 21st century skills. Students are expected to apply concepts learned in the course as well as ICT skills to collaboratively design digital games.

Learning Theories

The student as game designer approach is inspired by two important theories in learning and education which are constructivism and constructionism (Resnick, 2003).

1. Constructivism

According to constructivist theory of learning, learner is knowledge builder. Learner does not receive knowledge passively, but he/she interpret the knowledge received and then modify the knowledge in a form that acceptable to him/her. In other words, individual learner actively constructs new knowledge pursuant to his/her existing knowledge. Construction of new knowledge can be improved through social interaction. Vygotsky (1978) gave important to the role of social interaction in learning and cognitive development. He believed that collaboration between learner and teacher or more skilful peers will provide scaffolding to learner within the Zone of Proximal Development to construct new knowledge. However, no interaction would be beneficial if the new information is presented to students traditionally. Instead, students should be given the opportunity to explore the new knowledge. Bruner (1966) believed that learning and problem solving emerged out of exploration of new knowledge.

2. Constructionism

The theory of constructionism is built on the theory of constructivism which defines learning as knowledge construction in the student"s mind. In addition to the constructivist theory, constructionist theory of learning asserts that the construction of new knowledge happen felicitously in a context where students are consciously involved in the production of external and sharable artefacts (Papert 1991). This theory goes beyond the idea of learning-by-doing as indicated by Papert (1999a) that „*I have adapted the word constructionism to refer to everything that has to do with making things and especially to do with learning by making, an idea that includes but goes far beyond the idea of learning by doing*". Indeed, Papertian constructionism challenges the learner applying the knowledge being explored to construct more complex ideas or larger theory. This theory emphasizes the role of design (making, building or programming) (Kafai and Resnick, 1996) and external objects (Egenfeldt-Nielsen, 2006) in facilitating the

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knowledge construction. In this process, the designers (or learners) create artefacts which are significant to themselves based on their interests, learning styles and their experience, and shares their artefacts as well as the artefacts‟ designing process with others.

Computers play a role in the constructionist learning theory. Computers can be used as a building material (Papert, 1999a). The idea of using the computer as a construction material submitted by Papert is very different from the idea of using the computer as a tutor, tool and tutee put forward by Taylor (1980). For Papert and Franz (1988), a computer is a „material to be messed about with‟. Learning occurs when learners are 'messing about' with the computer. The introduction of computers is also able to change the context of learning (Papert, 1991). Computers can serve as a convivial tool (Falbel, 1991). The willingness of learners to learn will increase because they can use the computer in building artefacts (Papert, 1991). Papert (1980) has described that „*The computer is the Proteus of machines. Its essence is its universality, its power to simulate. Because it can take on a thousand forms and can serve a thousand functions, it can appeal to a thousand tastes*‟. However, he stressed that the main focus is not on the computer but on the minds of students (Papert, 1980).

Additionally, constructionist theory also values the diversity of learners and social aspects of learning. According to Kafai and Resnick (1996), this theory recognizes that learners can build relationship with knowledge through various ways, and community members can act as collaborators, coaches, audiences and co-constructors of knowledge in the constructionist learning environment.

Both constructivist and constructionist theories imply that learning depends on the learners themselves and learning can be enhanced through social interaction and discovery. Additionally, constructionist theory suggests that learning can be further enhanced if learners are involved in collaborative artefact designing projects using ICT as construction material.

Conceptual Framework of MyKimDG

Based on constructivist and constructionist theories, a module known as Malaysian *Kimia* Digital-Game (MyKimDG) has been developed as a mechanism for enhancing conceptual understanding and developing the 21st century skills. The conceptual framework of this study is summarized in Fig. 1.

1. Learning Approach

Learning approaches such as collaborative learning, discovery learning and learning through designing digital game (student as game designer) are integrated in MyKimDG.

Collaborative Learning. Activities in MyKimDG are designed so that students engage in discussion, share and exchange ideas in groups. Through this approach, triggering of cognitive conflict and restructuring of ideas will occur when students share their ideas from their own perspective. It also improves students‟ 21st century skills such as collaboration, communication and interpersonal skill because students are able to practice in the real world.

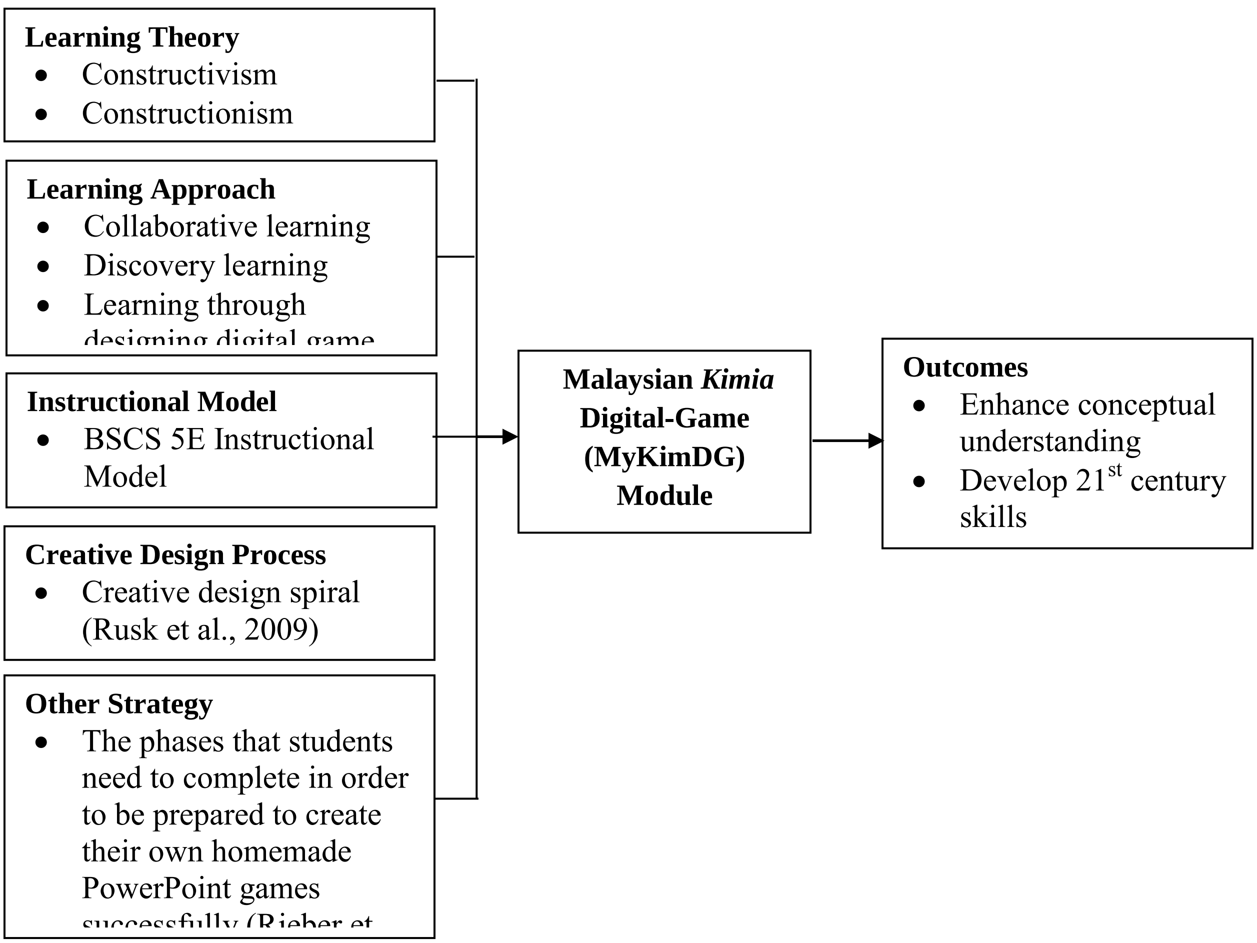

Fig. 1 Conceptual framework of study

Discovery Learning. Students are guided towards exploring chemical concepts. Students will gain deeper understanding when they are given opportunities to discover new concepts for themselves. It also lets students acquiring problem-solving skill, experiencing the exploration and discovery activities, and stimulating their own thinking. As students embark on the discovery process, teacher reminds them of the important of the process in learning. If they can perceive the values of the process, they will be motivated to learn chemistry. In this approach, students are empowered to take responsibility for their own learning and practice the 21st century skills in real situations.

Learning through Designing Digital Game. In MyKimDG, students are involved in designing PowerPoint games related to chemical concepts. They discuss in groups and apply the concepts learned to design PowerPoint games. With this, students can visualize the concepts in the sub-microscopic level.

PowerPoint game is selected as Microsoft PowerPoint software is available at all schools and the use of the software does not involve additional cost and complicated programming languages. The only technical skill that students need to master to design PowerPoint games is how to create custom animations. In addition, existing PowerPoint game templates are available online and can be modified by students to help them progressively master the game designing skills. This strategy is parallel with the development phases proposed by Rieber, Barbour, Thomas and Rauscher (2008). However, students are also encouraged to use other software like *Game Maker* and programming languages such as *Java*, *Logo* and *Scratch* if they are skilled in the software.

When students carry out their digital game designing project, they are guided to move through the creative design spiral (Rusk et al., 2009) in order to help them develop new ideas. Students are also given the autonomy to choose their own game design, plan and carry out the project based on the group‟s consensus. The students are also told that the PowerPoint game will be used to help their peers who face difficulty in learning the chapter. It is expected that this strategy will improve students‟ perceived competency, autonomy and relatedness, and hence increase their motivation in chemistry.

The learning through designing approach aims to deepen students‟ conceptual understanding in chemistry as cognitive conflict may be triggered during activities and hence, new understanding may discover. As the same time, it provides a platform for students to develop the 21st century skills.

2. Instructional Model and Strategy

Studies have revealed that mastery of science concepts will be enhanced if students become aware of their misconception. To help students realize their misconception and replaced it with scientifically acceptable concept (i.e. conceptual change), cognitive conflict strategy has been proposed by scholars such as Piaget (1977) and Posner, Strike, Hewson and Gertzog (1982). Therefore, the BSCS 5E Instructional Model (Bybee et al., 2006) designed to facilitate conceptual change is applied in MyKimDG.

To help students understand the chemical concepts, students are guided to explain macroscopic experience at the sub-microscopic and symbolic levels. It is known that conceptual understanding in chemistry involves making use of three main representations or levels. The triplet relationship is the key model in chemical education (Gilbert & Treagust 2009).

In this study, the phases of the BSCS 5E Instructional Model and Creative Design Spiral have been modified and standardized. The resultant phases are Inquiry, Discover, Produce, Communicate and Review. Table 1 shows the phases in MyKimDG, and related phases of the BSCS 5E Instructional Model and Creative Design Spiral.

Table 1. Phases in MyKimDG and related phases of the BSCS 5E Instructional Model and Creative Design Spiral

MyKimDG	BSCS 5E Instructional Model	Creative Design Spiral
Inquiry	Engage	Imagine
Discover	Explore	Experiment
Produce	Elaborate	Create
Communicate	Explain	Share
Review	Evaluate	Reflect

During implementation of MyKimDG, students are guided to experience and realise the phases. As the process is done repeatedly, new ideas are always generated and students" 21st century skills such as inventive thinking skills are developed. Students are expected to practice the process in everyday life and in the workplace.

Apart from that, it is expected that the acronym IDPCR can help students remember the five important clusters of 21st century skills which need to be integrated in the Malaysian science curriculum, i.e. Inventive thinking, Digital-age literacy, high Productivity, effective Communication and spiritual values (*nilai Rohani*). The five clusters of 21st century skills have been identified by Kamisah and Neelavany (2010). Table 2 showed the outline of instructional activities in MyKimDG.

Table 2. Outline of Instructional Activities in MyKimDG

Phase	Purpose	Activity
Inquiry *Predict, ask, hypothesize, identify problem, brainstorm*	1. Arouse students‟ interest 2. Access students‟ prior knowledge 3. Elicit students‟ misconceptions 4. Clarify and exchange current conceptions	1. Teacher shows discrepant events. 2. Students make observations and explain the phenomena at the sub-microscopic and symbolic levels. 3. Students discuss in groups and compare their ideas with their peers.
Discover *Investigate, experiment, explore*	1. Expose to conflicting situations 2. Modify current conceptions and develop new conceptions 3. Provide opportunities for students to demonstrate their conceptual understanding, and skills	1. Students perform hands-on and minds-on activities in groups. 2. Students are encouraged to engage in discussions and information seeking using ICT. 3. Students generate explanation of the observed phenomenon. 4. Students practise the skills needed in an experiment or activity. 5. Students are asked to communicate in groups and report back with their findings.
Produce *Create, construct, invent, build, design, tinker, elaborate*	1. Challenge and deepen students‟ conceptual understanding and skills 2. Provide additional time and experiences that contribute to the generation of new understanding	1. Students apply their new ideas by conducting additional activities 2. Students perform additional tasks that are more complex and involve HOTS. 3. Students carry out open-ended projects. 4. Students create digital games.
Communicate *Explain, share, discuss with peers, ask an expert, defend*	1. Provide opportunities for students to share their new understanding and skills 2. Provide opportunities for students to exchange their new understanding	1. Students report back with their new ideas and skills. 2. Students also listen to input from peers and defend their ideas. Peer‟s input may guide them towards deeper level of understanding. 3. Students compare their ideas with the

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		teacher's explanations.
Review *Check, evaluate, reflect, improve, repair*	1. Students assess their understanding, skills and competencies 2. Students think creatively for the purpose of improvement 3. Teachers evaluate student progress toward achieving the learning outcomes	1. Students reflect upon the extent to which their understanding, abilities and competencies have changed. 2. Students improve their ideas or skills based on reflection or input from peers. 3. Teacher conducts a test to determine the level of understanding of each student.

Implementation of MyKimDG

In the following section, the authors present a brief lesson in MyKimDG to the teaching and learning of a specific unit (i.e. preparation of insoluble salts) in the Malaysian Chemistry Curriculum which involved precipitation reaction.

Inquiry

1. Teacher demonstrates two reactions that may be used to prepare lead(II) sulphate:

	Reaction	*Observation*	*Chemical equation*
A	Lead(II) nitrate solution + sodium sulphate solution		
B	Excess solid lead(II) carbonate + dilute sulphuric acid		

2. Students record the observations and write the chemical equations involved.
3. Students describe how to obtain lead(II) sulphate from the mixture in Reaction A and B.
   (a) Draw the set-up of the apparatus is involved.
   (b) In your opinion, which reaction is more appropriate to prepare insoluble salts such as lead(II) sulphate? Explain your answer.
4. Students make a conclusion about the appropriate reaction to prepare insoluble salts.
5. Students share their findings with other groups.
6. Students are asked to explain the strategy used, i.e. inquiry-discovery.

Discover

1. Students plan experiments to prepare lead(II) iodide and silver chloride in group.
   (a) Discuss the materials needed to prepare lead (II) iodide and silver chloride.
   (b) Write the chemical equations involved.
   (c) Plan the procedures for experiment by constructing flowchart.
2. Students carry out experiment to prepare lead(II) iodide and silver chloride.
3. Students generate explanation of each phenomenon.
4. Students are asked to report back with their findings.

Produce

1. Students play a game related to the precipitation reactions involved in the preparation of insoluble salts.

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2. Students are asked to differentiate between a good game and a bad game.
3. Students are asked to improve the game to make it more educational and entertaining following phases of IDPCR, in order to help their peers who face difficulty in learning the concept.
4. Students are told that they may commercial their innovative product to benefit financially.
5. Students are reminded to apply 21st century skills during the project.

Communicate

1. Students share their digital games with other science or chemistry educators.
2. Students improve their digital games.

Review

1. Students plan and carry out experiments to prepare lead(II) chromate and barium sulphate in group.
2. Students write the chemical and ionic equation involved.
3. Students reflect upon the extent to which their understanding, abilities and competencies have changed.

Conclusion

In this study, collaborative learning, discovery learning and learning through designing digital game are integrated in the MyKimDG. The learning approaches will create supportive learning environments for student to learn chemical concepts meaningfully. Most importantly, MyKimDG allows students to practice the 21st century skills in real situations. In conclusion, the implementation of MyKimDG can help improve students" achievement in chemistry and their 21st century skills.

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The Effect of Electrolyte to Glucose Analysis using Electroanalytical Method by Platinum Wire Electrode

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Abstract

The effect of electrolyte to glucose analysis using electrochemical analytical method by platinum wire electrode has been carried out. The cyclic voltammetry were performed in a three electrodes system using Pt as a working electrode, an Ag/AgCl (saturated KCl) as reference electrode and platinum wire as the counter electrode. Electrochemical analysis of glucose was performed in various electrolytes. The result of the study showed the methods can be used for routine analysis of glucose in urine patient. Simplicity of sample preparation and use of low cost reagents are the additional benefit of this method.

Keywords: Electrolytes, glucose, platinum wire, electrochemical analysis.

Introduction

A glucose biosensor is a valuable tool for controlling various food and biotechnological processes as well as detecting and monitoring diabetes. Various techniques have been used in glucose biosensor, including electrochemistry, capillary zone electrophoresis, Fourier transform infrared spectroscopy, Fluorescence spectroscopy, surface plasmon resonance. Among those techniques, the electrochemistry has attracted significant attention because of its high sensitivity, low cost, simplicity and rapid response (Song et al. 2013).

Electrochemical oxidation of glucose has generated much interest over the years. It has been extensively studied for applications in glucose–oxygen fuel cells and, especially, in glucose sensors, whose optimization (in terms of response time, lifetime, sensitivity and selectivity) is required to improve the treatment of diabetes mellitus, a chronic disease affecting millions of people around the world. The electrocatalytic oxidation of glucose in alkaline medium was investigated using Cu, Ni, Fe, Pt and Au electrodes. Among them, platinum has been the most widely studied; in particular Beden et al. applied a reflectance IR spectroscopic technique to study the electro-oxidation process of d-glucose at platinum electrodes in alkaline medium. However, platinum also proved to be extremely non-selective and susceptible to poisoning by various components of blood and other physiological media over extended use.

Glucose is a very useful component of animal and plant carbohydrates. Quantitative determination of glucose plays an important role in biochemistry, clinical chemistry, and food analysis. Recently, various techniques are presented for glucose analysis, such as infrared spectroscopy, raman spectroscopy, photo acoustic spectroscopy, colorimetry, electrochemiluminescene and electrochemistry. Due to their high accuracy, low cost, rapidity, simplicity and better detection limits, electrochemical sensors with and without glucose oxidase (GOx) have been proved to be powerful approaches and attracted much more attention (Meng et al. 2009).

The electrochemical determination of glucose concentration without using enzyme is one of the dreams that many researchers have been trying to make come true. As new materials have been reported and more knowledge on detailed mechanism of glucose oxidation has been unveiled, the non-enzymatic glucose sensor keeps coming closer to practical applications. Recent reports strongly imply that this progress will be accelerated in 'nanoera'. This article reviews the history of unraveling the mechanism of direct electrochemical oxidation of glucose and making attempts to develop successful electrochemical glucose sensors. The electrochemical oxidation of glucose molecules involves complex processes of adsorption, electron transfer, and subsequent chemical rearrangement, which are combined with the surface reactions on the metal surfaces. The information about the direct oxidation of glucose on solid-state surfaces as well as new electrode materials will lead us to possible breakthroughs in designing the enzymeless glucose sensing devices that realize innovative and powerful detection. An example of those is to introduce nanoporous platinum as an electrode, on which glucose is oxidized electrochemically with remarkable sensitivity and selectivity (Park et al. 2006).

The greatest drawback of these enzymatic glucose sensors is their lack of stability originating from the intrinsic nature of the enzymes, which is hard to overcome. The activity of these enzymes can also be easily affected by temperature, solution pH, humidity, and toxic chemicals. Although GOx is quite stable compared with other enzymes, GOx-based glucose sensors are always exposed to possible thermal and chemical deformation (Zhu et al. 2012).

Advantages of detecting glucose without using enzyme are stability, simplicity and reproducibility. In this paper are studies of the effect of electrolyte to glucose analysis using electrochemical analytical method by platinum electrode.

Experimental

Solutions

All solutions were prepared by dissolving their analytical grade reagent (Merck) in deionised distilled water. KOH, NaOH, KNO_3 and buffer phosphate pH 6,8 was used as the supporting electrolyte. Buffer phosphate solution (pH 6.8) was prepared using 0.l M KH_2PO_4 (Merck) and 0.1 M NaOH (Merck).

Preparation of platinum electrodes

Platinum metals sheet (99.98% purity, 0.5 mm thick, Aldrich Chemical Company) was used to prepare Pt electrodes. The metal sheet electrodes were prepared in square cut of 1 cm by length and wide respectively. The metal sheet electrodes were connected to silver wire with silver conducting paint prior covered with epoxy gum.

Electrochemical behavior of the electrodes

PGSTAT 100 N 100 V/250 mA (Metrohm Autolab) was used for electrochemical behavior measurements; data acquisition was accomplished using the software from Metrohm. Cyclic voltammetry experiments were performed in a three electrodes system using Pt metal sheet as a working electrode (anode), an Ag/AgCl (saturated KCl) or SCE as reference electrode and platinum wire as the counter electrode. All potentials given are with respect to the SCE reference electrode.

Experimental procedure

The electrochemical behavior process of glucose was performed in a solution of KOH at room temperature. The electrochemical studies by cyclic voltammetry (CV) were performed in 25 mL capacity glass electrochemical cell.

Result And Discussion

The cyclic voltammetry of glucose in neutral condition (phosphate buffer)

Figure 1 shows the cyclic voltammogram of buffer phosphate (without glucose) with the sweep potential from potential -1000 up to +1000 mV, and then return from +1000 mV up to -1000 mV. Figure 1 shows the cyclic voltammogram of 0.1-1.0 M glucose in buffer phosphate . The peaks represent the anodic peaks. These peaks related to the oxidation of absorption of hydrogen, double layer and Pt-oxide.

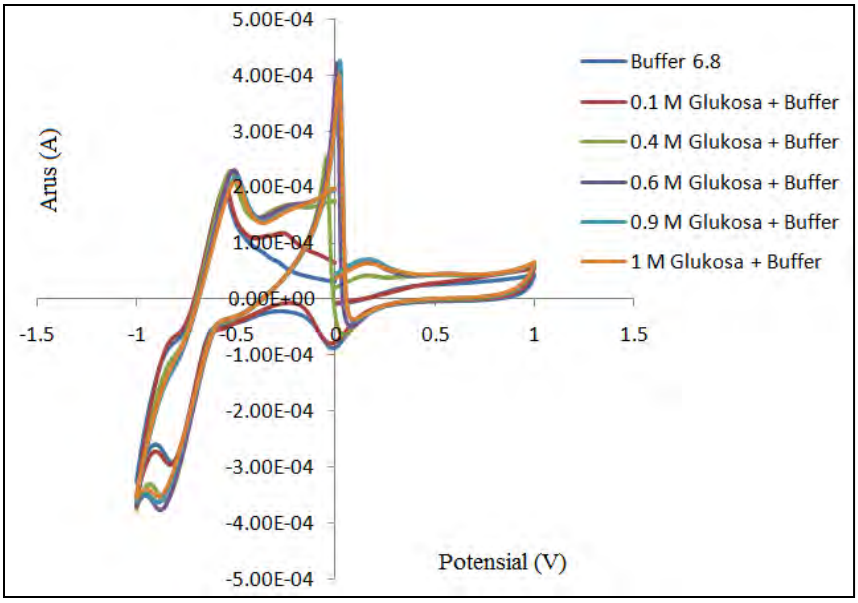

Figure 1. Cyclic voltammogram of glucose with various concentration of buffer phosphate pH 6.8, scan rate 100 mVs^{-1}. Pt electrode was used as working and counter electrode. Ag/AgCl was used as a reference electrode.

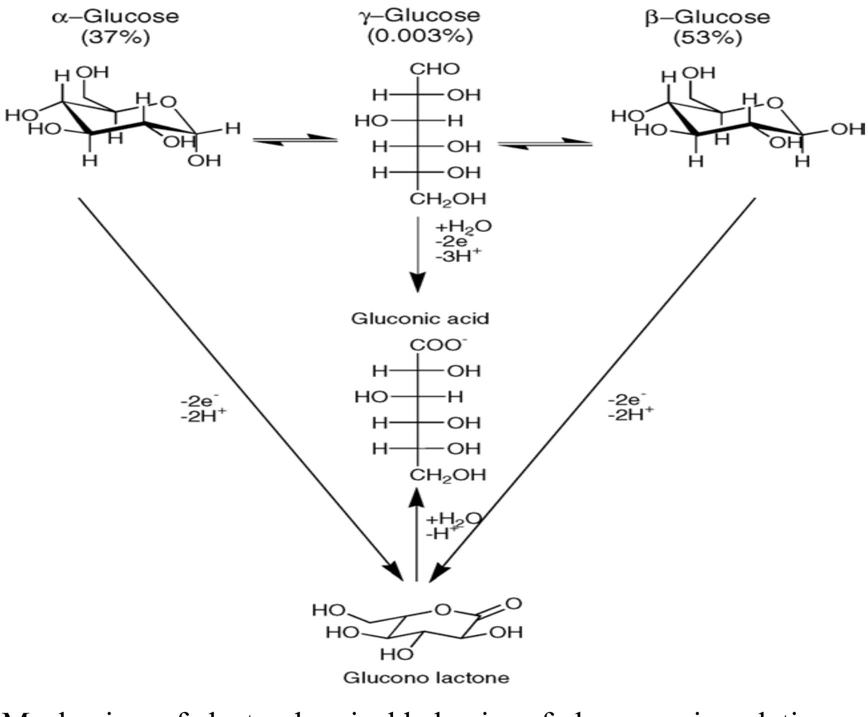

Figure 2 Mechanism of electrochemical behavior of glucose using platinum electrode (Park et al. 2006)

As a result of early investigations on the electrochemical oxidation of glucose on platinum in neutral phosphate buffer therewas an agreement that the electrochemical oxidation of glucose involves the dehydrogenation at C1 carbon glucose is the most reactive species among the possible anomeric forms. The poor reactivity of glucose is supposedly attributed to the geometric orientation of the hydrogen atom bound to the anomeric carbon. Generally the electrochemical oxidation of glucose has been discussed in three potential ranges. In Figure 1, the region between 0.15 and 0.35V versus RHE (reversible hydrogen electrode) is called as 'hydrogen region'. Glucose produces the unique behavior of electrochemical oxidation in the hydrogen region when platinum is used as a working electrode. We cannot observe voltammetric behavior like this with electrode materials other than platinum (Park et al. 2006).

For instance other organic substances such as alcohols, acids, and aldehydes do not show the oxidative current in the hydrogen region like that shown in Figure 1. The glucose oxidation in hydrogen region is associated with the adsorbed hydrogen atoms. The reactive center for the reaction is the hemiacetal group of glucose (Park et al. 2006). Adsorbed glucose and/or products dominate the reaction. The proposed mechanism is as follows: 'Double layer region' means the region between 0.40 and 0.80V versus RHE. In the double layer region, the cyclic voltammogram measured in phosphate buffer at pH 7.5 shows two separate oxidation peak observed only at low scan rates. For example, the peaks at $5 mVs^{-1}$ appear at 670 and 750 mV versus RHE. The oxidation peak current decreases as anions or organic species, particularly glucono lactone, are adsorbed. Neither pH between 5.5 and 9 nor potential applied between 0.2 and 0.5 V versus RHE affects the surface coverage by organic adsorbed. However, the adsorption is a function of applied potential and glucose concentration. And the surface becomes less adsorptive when potential more positive than 0.5V is applied. The proposed mechanism is below (Figure 2). No result from systematic study has been reported yet on the voltammetric behavior in the oxide region of more positive than 1.1V versus RHE. In this region, glucose reacts with the produced platinum oxide layer. The poisoning product of lactone-type are decomposed by further oxidation (Park et al. 2006).

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The cyclic voltammetry of glucose in KNO_3

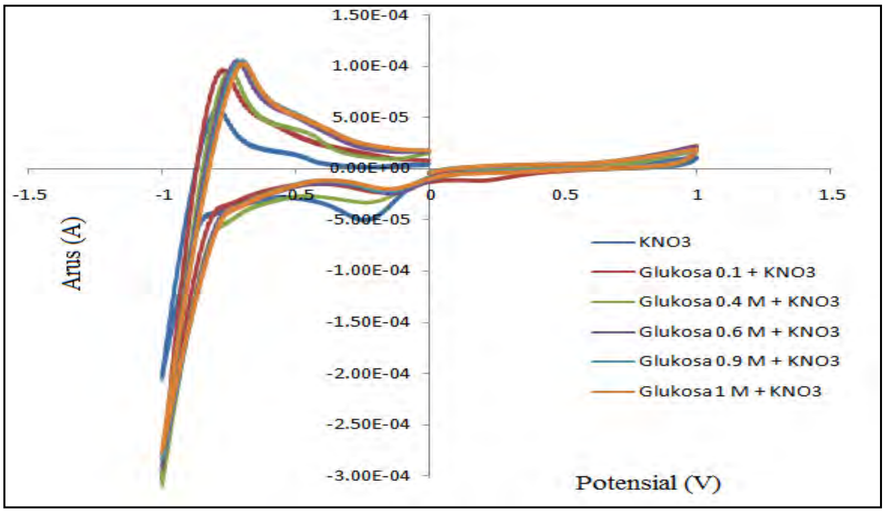

Figure 3. Cyclic voltammogram of glucose with various concentration of 0.1 M KNO_3, scan rate 100 mVs^{-1}. Pt electrode was used as working and counter electrode. Ag/AgCl was used as a reference electrode

Figure 3 shows the cyclic voltammogram of 0.1 M KNO_3 (without glucose) with the sweep potential from potential -1000 up to +1000 mV, and then return from +1000 mV up to -1000 mV. Figure 1 shows the cyclic voltammogram of 0.1-1.0 M glucose in 0.1 M KNO_3. The peaks represent the anodic peaks. These peaks related to the oxidation of absorption of hydrogen, double layer and Pt-oxide.

The cyclic voltammetry of glucose in basic condition

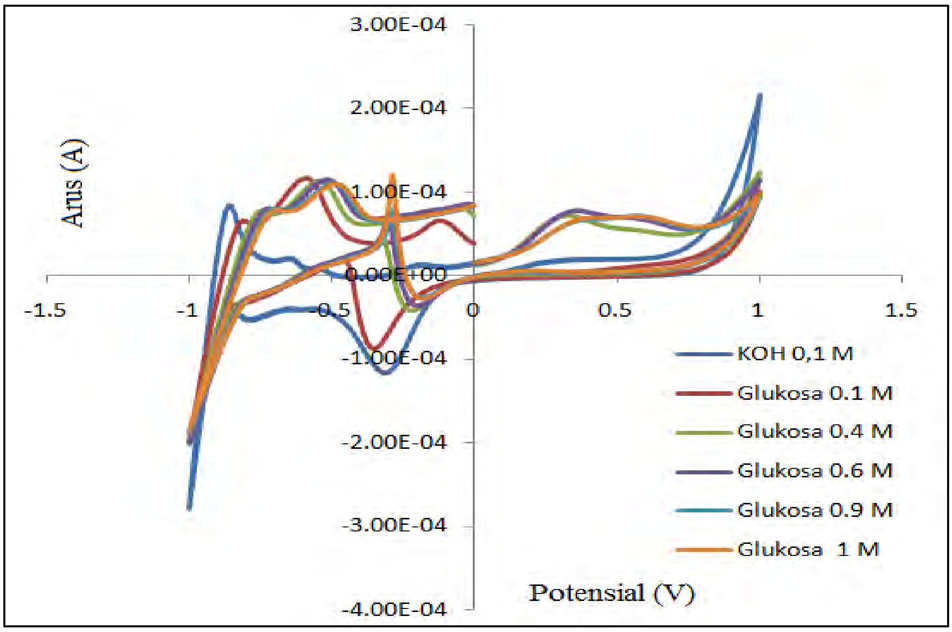

Figure 4. Cyclic voltammogram of glucose with various concentration of 0.1 M KOH, scan rate 100 mVs^{-1}. Pt electrode was used as working and counter electrode. Ag/AgCl was used as a reference electrode

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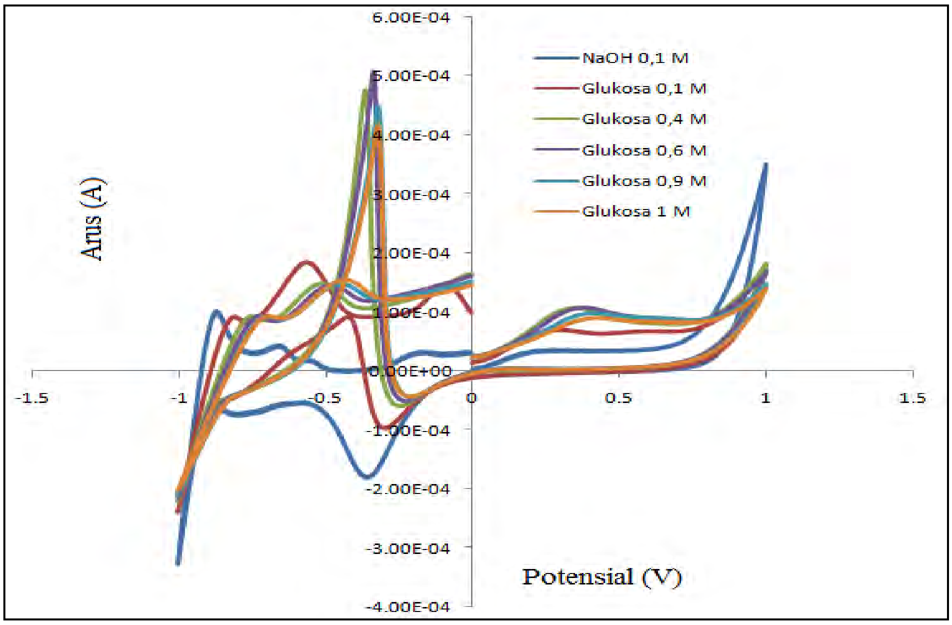

Figure 5. Cyclic voltammogram of glucose with various concentration of 0.1 M KOH, scan rate 100 mVs^{-1}. Pt electrode was used as working and counter electrode. Ag/AgCl was used as a reference electrode

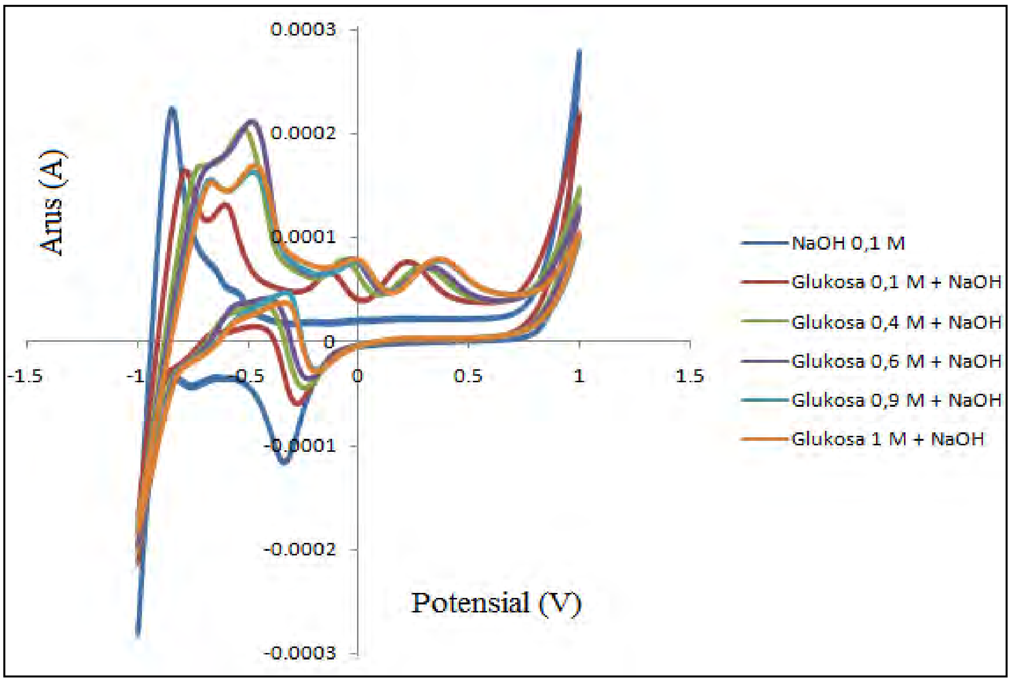

Figure 6. Cyclic voltammogram of glucose with various concentration of 0.1 M KOH, scan rate 200 mVs^{-1}. Pt electrode was used as working and counter electrode. Ag/AgCl was used as a reference electrode

The first step is at a potential more positive than the potential used for detection, and the second step lies at a more negative potential. The effect of these two potential steps can be understood by examining the rotating disk voltammogram of a gold electrode in 0.1 M

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sodium hydroxide in the absence (a) and in the presence of glucose (b) When no glucose in present, there are two major features in the rotating disk voltammogram. The anodic current on the forward scan at A is due to the formation of a surface oxide layer, and the cathodic current on the reverse scan at C is due to dissolution of this layer. The addition of glucose leads to a considerable increase in the anodic current on the forward scan at E and F due to the oxidation of the aldehyde and alcohol groups at the bare electrode surface. The current for these catalytic oxidations is attenuated at more positive potentials since the formation of the oxide layer blocks the active sites on the electrode surface. However, the current at G is still larger in the presence of glucose due to oxidative desorption of the adsorbed oxidation products. The dissolution of the oxide layer is also used for other pulsed detection techniques (Bott 1998).

The oxidation of glucose at platinum in alkaline solutions has been understood as illustrated in Figure 2. Instead of hydrogen adsorption, the chemisorption of glucose on bare platinum takes place initially. This step is a kind of ‘dehydration step’. When the potential in the hydrogen region under 0.3V versus RHE is applied, the adsorbed dehydrated intermediate is further oxidized to form weakly adsorbed gluconate. In double layer region between 0.3 and 0.6V, further oxidation of the adsorbed dehydrated intermediate produces more weakly adsorbed gluconate. The adsorption strength tends to weaken as the potential applied increases. At potentials more positive than 0.6V and up to the anodic limit, the adsorbed dehydrogenated intermediate is oxidized to form a glucono lactone without cleavage of the C O C bond. The glucono lactone desorbs slowly and eventually becomes gluconate as a result of hydrolysis in the basic media (Park et al. 2006).

These results show that glucose is hardly adsorbed at the surface of Pt modified electrode and the electrode reaction is controlled by the diffusion of glucose in the solution. Meanwhile, this also indicates that the faradic response of a sluggish reaction like glucose oxidation would be significantly improved by the Pt. With the increase of potential scan rate, both the peak potentials of anodic peaks and chatodic peaks move to more negative values, while the peak current of anodic peaks first increases and then decreases after its peak potential below 0 V. It can be explained by the fact that when the potential is below 0V, the second oxidation of glucose corresponding to anodic peaks would not occur, hence low peak current would be observed. It should be pointed out that the catalytic peak here was only obtained at higher

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concentrations of glucose (>0.1mM) and could not be observed in the micromolar range (Zhu et al. 2012).

Conclusion

The electrochemical behavior process of glucose was performed using cyclic voltammetry in various electrolytes. Basic solution is good electrolyte for studies of electrochemical behavior glucose using platinum electrode.

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