Reforms in science curricula in last six decades: Special reference to physics

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Abstract

This review paper discusses the reforms in science curricula particularly those related to physics curricula which took place after the launch of the Sputnik by the Soviet Union in 1957. These reforms have started at national level as well as international level by establishing curriculum facilities around the end of 1960s. This review informs science educators about previous research in science curricular reforms, the struggles of global physics instruction transformation starting from United State of America (USA) and United Kingdom (UK), and current science/physics education researches. Recent advances in physics curriculum development as well as some important science reform programmes that have been done in Africa are also discussed. The paper also highlights the Competence Based Curriculum developed by Ministry of Education- Rwanda Education Board. The paper updates science/physics educators on evaluation of effectiveness of various instructional methods used in the past facilitating the identification of potential reform approaches to be successful in future. Some practical recommendations that can be used for effective teaching and learning of science, especially for physics are also outlined.

Keywords curriculum; reforms in science; science curricula; physics curricula

Introduction

Curriculum is one of the abstract concepts in educational literature. Radha Mohan (1995) defined curriculum as the planned and guided learning experiences and intended outcomes, formulated through systematic reconstruction of knowledge and experience (Mohan, 1995).Curriculum was also defined as the vehicle through which a country empowers its citizens with the necessary knowledge, skills, attitudes and values that enable them to be empowered for personal and national development (Kabita & Ji, 2017). In this line, curriculum should meet the needs of the individual citizens and the nation. A high quality curriculum is the key indicators of effective education. In order to keep pace with the changing global situation and to address issues in conflict with inclusive access to education, there should be regularly updated curriculum for its adequacy, relevance and coherence (REB, 2015). In agreement with efforts to improve the quality of the curriculum, science/physics curriculum has been gone through different reforms worldwide.

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Science development efforts were sparked off during the 1960s and 1970s after the sudden launching of Sputnik by Soviet Union in 1957 (Meltzer & Otero, 2015). According to some studies in USA, before 1957, science/physics curriculum for high schools and college was made of syllabus, a text, a collection of standard problems, and a set of prearranged laboratory experiments (Van den Akker, 1998). After Sputnik launching, the mode of science teaching/learning and the nature of the science curriculum existing in the USA and other nations of the world were reviewed and different science education curricular reforms took place (Van den Akker, 1998; Ojimba, 2013); Besides, the Rwandan nation became a part of these curriculum development efforts with the birth of Competence Based Curriculum (CBC) (REB, 2015).

Considering the ineffectiveness of some of these reforms, it was felt that science curriculum reform must take into account the principles of cognitive science related to construction of knowledge and hence, much attention was given to students' prior knowledge of science and the relationship between students' prior knowledge and scientifically accepted principles. The most important consideration of these curricular reform efforts was very influenced by the fact that there was total dissatisfaction on how science was still traditionally being taught leading to the decreasing popularity of science among students as evidenced by the declining number of students choosing science subjects (Ojimba, 2013). Additionally, many research studies have shown that students exposed to the traditional approach end up with poor understanding of scientific concepts. In addition, the traditional approach it was argued did not adequately prepare future citizens to understand science and technology issues in a rapidly evolving study (Ojimba, 2013).

The paper aims at reviewing on reforms in science curricula in last six decades staring from USA and focusing on physics curriculum. It discusses the reforms in science curricula with special reference to physics curricula, which took place after 1957. This review ought to help science educators to become aware of previous research in science curricular reforms, the struggles of global physics instruction transformation (starting from USA), and current science/physics education research and national and regional curriculum reforms. In addition, the review will update science/physics educators on evaluation of effectiveness of various instructional methods and instructional materials used in the past facilitating the identification of potential reform approaches to be successful in future. Some practical recommendations that can be used for effective teaching and learning of science, especially for physics are also outlined. The paper is made of six sections including the introduction. In section 2, a brief historical overview of reforms in science curricula is provided. In section 3 and 4, the early trends in physics curriculum development and the recent advances in physics curriculum development are respectively discussed. Finally, summary and recommendations of the paper and some recommendations are provided in section 5 and 6 respectively.

Brief historical overview of reforms in science curricula

The reforms that took place in 1960s were done cooperatively by different influences including science teachers, academic scientists, political and economic comparisons, theories of teaching and learning as well as philosophical ideas about science and science education (Fensham, 1992). In order to make serious reform for science curriculum, scientist teachers were supported by political and economic comparisons. Both academic scientists and science teachers worked together to produce new curriculum materials (Fensham, 1992).

Just after 1957, prominent projects were initiated in the USA and the UK and these early curriculum reforms employed scientists as the project directors. Around that period, the main emphasis in the science curricula reforms was on the structure of the scientific disciplines and modernization of the curriculum content of the various science subjects. Later, the reform of science curricula emphasized the relevance of science to society also known as the era of development projects or discipline-knowledge curricula (Van den Akker, 1998).

At that time, the leadership of science curricula reform projects by prominent scientists counseled by educational theorists primarily characterized science curricula. During this era, all the science curriculum reform projects included the content to be taught and the ways in which it is taught. The structure of the discipline was accentuated in addition to text books and worksheets prepared with emphasis to scientific concepts and scientific process. Scientific knowledge was considered as the primary goal while scientific methods were considered as means of achieving this goal. Hand on activities were emphasized in concept-based mainly curricula where practical work was considered very important (McDermott, 1991; Van den Akker, 1998; Wallace & Louden, 1998)

During the first wave of reform, Physical Science Study Committee (PSSC) Project (Turner, 1984; Meltzer & Otero, 2015), Biological Sciences Curriculum Study (BSCS) and Chemical Educational Materials Study (CHEMS) in the USA and Nuffield in the UK were major science curriculum projects. Elementary School Science (ESS) and Science-A Process Approach (SAPA) were major primary science curriculum projects. Turner David (1984) argued that both PSSC and Nuffield "O"-level physics courses were traditional and their non innovative nature reflected curriculum developers' attitude towards an acceptable physics course (Turner, 1984). One can mention that the endpoint of the first wave of reform was not the same across countries (McDermott, 1991; Mohan, 1995; Van den Akker, 1998; Wallace & Louden, 1998).

Despite the effort made to bring up to date content and goals of textbooks within the new curricula in order to ensure that scientific validity of the content of the books was careful reviewed, some limitations were reported. Among these limitations, one is that the new science curricula were expensive and did not reach to substantial number of disadvantaged students. Furthermore, the courses were too difficult and abstract for most students and little attention was paid to students' prior knowledge of science. Researchers argue that the main reason for the failure of these curricula lack of good match between the teachers and the curriculum (Walberg, 1991; McDermott, 1991; Wallace & Louden, 1998). College Introductory Physical Science (CIPS) and Project Physics Course are some projects in which efforts were made to use new physics curricula (Meltzer & Otero, 2015). Modifying the instructional methods which were conducted in an individualized, self-paced manner, with laboratory investigation, observation, and manipulation preceding all discussion and motivating the formation of concepts and models is also one of these efforts (Arons, 1972). The emergence of the emphasis on the importance of scientific literacy started while many educationists argued that the emphasis on the discipline of science is not sufficient due to the decreasing of the number of development initiatives of the reform (Van den Akker, 1998; Wallace & Louden, 1998; Meltzer & Otero, 2015). This emergence was linked with the emphases on scientific relevance including science, technology and society.

In the second wave of reform of science curricula, the emphasis was put on science as relevant knowledge and socially relevant base for science education. In addition, educationists promoted an increased role for teachers in the curriculum process. During this second reform, little attention was given to students' prior understanding of science. Individualized Science Instructional System (ISIS) from the USA, the Nuffield Science Teaching Project (NSTP) from the UK and the Australian Science Education Project (ASEP) from Australia are some examples of major science curricula during the second wave of reform (Wallace & Louden, 1998).

The third wave of science curriculum reform associated with principles of cognitive science. During this wave, more attention was given to students' prior knowledge of science and the relationship between students' prior knowledge and scientifically accepted principles (Wallace & Louden, 1998). It was reported that many learners come to science class with some preconceptions which, in general, contradict with scientifically accepted principles and concepts of science. For effective learning, there is a need of some changes in the existing knowledge in case new knowledge conflicts with existing knowledge (Resnick, 1983; Redish E., 1994; Mestre, 2001). Much of the science curricula related to third wave of reforms attempt to bridge the gap between the imperfect knowledge of learners and the scientifically accepted principles. During this wave of reform, several curricula were developed grounded on constructivist approach to learning and science was referred as imperfect knowledge (Wallace & Louden, 1998). The Introductory University Physics Project (Rigden, Holcomb, & DiStefano, 1993), Project 2061 (AAAS, http://www.project2061.org), Biology Concept Framework (Khodor, Halme, & Walker, 2004) are some of major recent science curriculum projects.

The most ambitious and long-term effort in science reforms at secondary level is *Project 2061* that started when Halley comet was near the earth in 1985 and it was considered that children starting school would live to see its return in 2061. This project is sponsored by the American Association for the Advancement of Science (AAAS) and it focuses on scientific literacy (Walberg, 1991; Lopez & Schultz, 2001). Project 2061 conducts research and develops tools and services-books, CD-ROMS, on-line resources, professional development, and public outreach that educators, researchers, parents and families, and community leaders can use to make critical and lasting improvements in the nation's education system (AAAS, http://www.project2061.org). Other efforts are being made to include some topics, which are uncommon in school science curricula, such as the nature of science, mathematics and technology, scientific inquiry and methods, relation between science, mathematics and technology and how they relate to society.

Furthermore, there are some important science reform programmes that have been done in Africa and this has started at national level as well as international level by establishing curriculum facilities around the end of 1960s. The African Primary Science Programme (APSP), East African School Science Project, Science Education Programme for Africa (SEPA), Boleswa Integrated Science (Botswana, Lesotho and Swaziland), PROTEC programme (South Africa), Primary Science Education Project (Malawi), Science by Investigation (Botswana), New Science Curriculum (Ethiopia), Project for Science Integration (Ghana), Science Teachers' Association of Nigeria (STAN) Curriculum Development Project, Core Course Integrated Science (Sierra Leone), Integrated Science Project (Swaziland) are some of important science curricular reforms in Africa.

For the development of new science curricula in different countries, social and cultural contexts were also taken into consideration. Zimbabwe and Malaysia are some of countries in which science curricula reforms and those for physics have been influenced by social and cultural perspectives. A new science curriculum was developed in context of national conditions, taking into consideration the practical, economic, political and cultural issues in Zimbabwe (Wright, 1982). In Malaysia, the development of science/ physics curricula was significantly influenced by international trends but also by the country's socio-political development (Lee, 1992). Malaysian science/physics education is distinctive in some aspects, for example, it is taught in the national language, it is about science in tropical countries, and religious values are taught through science education.

In Rwanda, the recent curriculum reform focuses on student-centred pedagogy, and intended learning outcomes and competencies including general transferable skills. Some of these skills are developing problem solving to real life physical situations, awareness of the nature of science, applying knowledge of scientific inquiry to real life situations, working independently and in collaboration and organizing ability among others. Many factors including the relevancy of the curriculum, the necessary and sufficient pedagogical approach by teachers, the assessment strategies and the necessary and sufficient instructional materials influence what children are taught, how well they are taught as well as acquired competences (REB, 2015). The issues of lack of appropriate skills in Rwandan education system have been addressed by the shift from a knowledge-based curriculum to a competence-based curriculum. This shift was encouraged by the imperative need of developing a knowledge-based society and the growth of regional and global competition in the jobs market (REB, 2015). Teachers playing the crucial role to the success of the curriculum delivery help learners getting the opportunity to apply what they have learned in real life situations and to make a difference in their own life (REB, 2015).

Early trends in physics curriculum development

The first major project for physics curriculum development that was led by J.R. Zacharias with a team of brilliant physicists such as Nobel Laureate Edward M. Purcell, P. Morrison is Physical Science Study Committee (PSSC) Project initiated during 1956–1960 (Meltzer & Otero, 2015). This project was started at Massachusetts Institute of Technology and it was mainly designed for the academically superior students. New laboratory experiments were completely designed by the first-rate experimental physicists for this project and eminent physicists such as Nobel laureates G. Gamow and R. Wilson, H. Bondi and others have written other monographs. It was estimated that for about 2 decades, more than 20% of American students studying high school physics used the text and laboratory materials developed by the PSSC. The main aim of PSSC was to focus upon the conceptual structure of physics and teach the subject as a discipline (Swartz, 1991; Mohan, 1995; Lijnse, 1998).

Moreover, a new type of physics approach, known as Project Physics or widely known as Harvard Project Physics was developed by F.J. Rutherford, G. Holton and F.G. Watson. This project was designed for high school students who were not using PSSC (Meltzer & Otero, 2015). Designing a humanistically oriented physics course, attracting more students to the study of introductory physics, and finding out more about the factors that influence the learning of science were three major goals Project Physics (Rutherford, Holton, & Watson, 1970). The textbooks, monographs, new laboratory experiments and lab manuals were also developed in this project. However, the Project Physics could not address its third goal and it failed in expanding the audience of good high school physics students (Swartz, 1991).

In UK, Nuffield O-level Physics was developed. This project included lots of experiments to teach students the process of science. Physics was presented to students as a growing fabric of knowledge in which one part was linked with other parts in a coherent way (Mohan, 1995; Lijnse, 1998; Wallace & Louden, 1998). In line of taking into consideration social and cultural contexts for different countries while developing new physics curricula, Nuffield-based physics courses were adapted for the reform of physics teaching in Malaysian schools (Swetz & Mohd Meerah, 1982).

The Project Physics and Nuffield O-level Physics projects that have been mentioned were mainly aimed to high school physics students and focused largely on teaching the basic disciplinary structure of physics (Mohan, 1995; Lijnse, 1998; Swartz, 1991). It was found that PSSC Physics and Project Physics were not as effective as had been expected due to the fact that they well matched only to the promising students as little attention was paid on students' prior understanding of physics (McDermott, 1991).

Other developed science projects included Elementary Science Study (ESS), Science Curriculum Improvement Study (SCIS), and Science- A Process Approach (SAPA). The ESS and SCIS projects were for elementary schools focusing on simple experiments that illustrate physical models for everyday phenomena (Wilson, 1991). The SAPA project that was initiated by the American Association for the Advancement of Science (AAAS) was influenced by the ideas of psychologist Robert Gagne. The theory of Robert Gagne is particularly related to hierarchical development of science process skills such as observing, classifying, measuring, interpreting data, inferring, communicating, controlling variables, developing models and predicting. Even if SAPA project was one of the most expensive projects, it was the least used and least influential (Swartz, 1991).

Recent trends in physics curriculum development

In physics education, there are considerable developments between presents situation and the post-Sputnik era. Among them are both growing body of knowledge about student's understanding of physics (Hestenes, 1996; Gobert & Buckley, 2000; Greca & Moreira, 2000; Hrepic, Zollman, & Rebello, 2010) and the enormous advance in technology that has taken place (McDermott, 1991; Mohan, 1995; Redish, Saul, & Steinberg, 1997; Wieman, 2015; Ulukök & Sari, 2016). A great number of physicists, cognitive psychologists, and science educators have been engaged in research in physics education. Over the past 20 years, many traditional courses, curricula, instructional methods and text books have been questioned. Several physicists have developed curricula that focus specifically on effective teaching methods using physics education research findings about students' difficulties combined with knowledge from scholars of education and cognitive psychology who find that most persons learn most effectively in active-engagement environments in which social interaction takes place (Hestenes, 1996; Hake, 1998; Von Korff, et al., 2016). Many new and reshaped courses and curricula have been developed, using new instructional methods including more interactive engagement, focusing on problem solving, conceptual understanding, including more cooperative learning and using advance technology (McDermott, 1991; Redish & Steinberg, 1999; Thacker, 2003).

Some recent physics curricula

Some recent physics curricula such as the Overview, Case Study (OCS), The MAOF curriculum, microcomputer-based laboratory (MBL) curricula, Workshop Physics curriculum, as well as Integrated Math, Physics, Engineering, and Chemistry curriculum (IMPEC) are discussed in this section.

The Overview, Case Study (OCS) Physics curriculum was developed by Van Heuvelen in 1991 (Van Heuvelen, 1991). In the OCS, semesters are divided into a small number of conceptual knowledge blocks emphasizing physics problem solving. In OCS, in helping students reasoning about physical processes, they start each block by constructing qualitatively the basic physics concepts using qualitative representations. After this first process, students use mathematics and multiple representation techniques to solve problems. More complex case study problems are work on at the end of each block. The results show that OCS Physics method produced promising gains in student qualitative understanding, in their ability to solve problems and in their ability to form and access a physics knowledge organization (Van Heuvelen, 1991; Yadav, 2005).

The MAOF curriculum (abbreviation in Hebrew) which relates large parts of mechanics and electromagnetism to each other via the basic concepts of potential and field, using a unified approach have been developed by Bagno et al. in 2000 (Bagno, Eylon, & Ganiel, 2000). The instructional method of MAOF included problem solving, conceptual understanding and construction of knowledge structure, as well as the formation of concept maps. Students who used MAOF were found to significantly improve their ability of understanding of mechanics and electromagnetism.

Thornton and Sokoloff (1998) developed two active learning microcomputer-based laboratory (MBL) curricula, Tools for Scientific Thinking (TST) Motion and Force, and Real Time Physics (RTP) Mechanics. These curricula were designed to allow students to take an active role in their learning and encourage them to construct physical knowledge for themselves from actual observations. They also developed a strategy for more active learning which engages students in the learning process using microcomputer-based Interactive Lecture Demonstrations (ILDs). This strategy converts the usually passive lecture environment to a more active one. There was found strong evidence of significantly improved conceptual learning in both MBL curricula and ILDs strategies (Thornton & Sokoloff, 1998).

Workshop Physics curriculum, a calculus-based physics without lectures, is based on the philosophy that valuating acquiring transferable skills of scientific inquiry more that both problem solving and the comprehensive transmission of descriptive knowledge about the enterprise of physics (Laws, 1991). Workshop Physics curriculum is an activity-based curriculum emphasizing transferable inquiry skills based on real experience. In order to facilitate activity-based learning, new apparatus and computer tools are used in the curriculum. Activities for students include discussing with teachers and colleagues, qualitative observations, data collection, guided equation derivations, problem solving, use of spreadsheets, computer-based laboratory tools and video analysis for the collection and analysis of data and for analytical and numerical modeling using spreadsheets are activities for students while using Workshop Physics (Laws, 1991; Laws, 1997a; Yadav, 2005). The Workshop Physics Activity Guide providing for both instructors and students guidance was developed by Priscilla Laws (Laws, 1997a; Laws, 1997b).

An integrated curriculum knows as Integrated Math, Physics, Engineering, and Chemistry curriculum (IMPEC) for freshman engineering students have been offered by North Carolina State University (Beichner, et al., 1999). The physics component of the curriculum provided the highly collaborative, technology-rich, activity based learning environment. A wide variety of hands-on physics activities were either developed or adapted from existing curricula, such as Workshop Physics (Laws, 1997b), Physics by Inquiry (McDermott & Others, 1996), Peer Instruction (Mazur, 1997). While examining the impact of this curriculum on learning of the students, both qualitative and quantitative research results indicate that the instruction had a substantial positive effect on the students' conceptual understanding, problem-solving skills, attitudes toward the curriculum, and confidence levels (Beichner, et al., 1999).

Some big physics curriculum projects

Some big projects involved many persons and/or extent for a long period are now discussed. Among these projects, Physics by Inquiry, Interactive-Engagement, curriculum for the Institute of Physics, Discovery Project as well as the Introductory University Physics Project (IUPP) are discussed.

Under the leadership of Lillian C. McDermott, Physics Education Group at University of Washington has for many years been engaged in a coordinated program of research, curriculum development, and instruction (McDermott, 1991). They strived to produce curriculum that is friendly to students through a three-part process: (a) conducting systematic research of students understanding, particularly the misconceptions of students, (b) using the results of this research to guide the development of curriculum, and (c) designing, testing, modifying and revising their instructional materials in a continuous cycle on the basis of classroom experience

(McDermott, 1991; McDermott & Shaffer, 1992; McDermott, Shaffer, & Constantinou, 2000; Yadav, 2005). McDermott and Others (1996) also produced a set of laboratory-based module, known as Physics by Inquiry and Tutorials in Introductory Physics.

The Interactive-Engagement (IE) physics curricula are also discussed in this paper. The main IE physics curricula included in the study of Hake were: Overview, Case Study Physics (OCS), Peer Instruction (PI), Microcomputer-based labs (MBL), etc. In 1999, while conducting a survey of a few thousand physics students, Redish and Steinberg mainly focused on IE physics curricula including Workshop Physics and Tutorials in Physics (Redish & Steinberg, 1999). On the other side, Hake's study was mainly including OCS, PI as well as MBL (Hake, 1998; Von Korff, et al., 2016).

A curriculum for the Institute of Physics has been developed by a large team of physics teachers under the leadership of Jon Ogborn. Two textbooks and a very large collection of resources for teachers and students, stored on two CD-ROMs have been developed. Advancing Physics published by Institute of Physics Publishing was the resulting module from this curriculum (Ogborn, 2002). Discovery Project offering Introductory Physics to practicing elementary science teachers using an interactive-engagement curriculum has been started by Ohio State University (Wilson, 1991).

The Introductory University Physics Project (IUPP) started in 1987. The development of the new course models in this project was guided by three principles including the need of reduction of the total course content, coherency in the presented course content, and the course content made mainly by contemporary. Among 13 course model curricula that were submitted in response to a national call for proposals, only 4 were selected for full development and testing including Six Ideas That Shaped Physics by T.A. Moore (Moore, 1998), Structures and Interactions by D. Neuenschwander, Particles Approach by R. Enger and J Head Physics in context by J. Barojas (Rigden, Holcomb, & DiStefano, 1993; Coleman, Holcomb, & Rigden, 1998).

Among these chosen 4 models, only Six Ideas That Shaped Physics model that was developed by T.A. Moore in 1998 is briefly discussed here. This model consists of 6 units each with its own theme. The goal of Six Ideas is to help physics students achieving a good level of competence in the four cognitive skills such as applying basic physics concepts and principles to realistic situation, solving realistic problems, resolving their misconceptions as well as organizing basic physics concepts and principles hierarchically (Rigden, Holcomb, & DiStefano, 1993; Coleman, Holcomb, & Rigden, 1998; Moore, 1998).

Physics instructional Methods and instructional materials

In addition to the studies carried out by the curriculum developers, several independent studies also clearly showed that the use of innovative instructional methods and specific instructional materials can increase physics-course effectiveness considerably better than that obtained using traditional methods (Hake, 1998; Redish & Steinberg, 1999). This paper discusses some physics instruction methods as well as some specific instructional materials that have been developed by different researchers staring from Peer instruction, and Active Learning Problem Sheet.

Studies show that cooperative learning in science education is a promising innovation for the social and cognitive development of students. Peer Instruction is teaching method developed by Eric Mazur in 1997. This teaching method actively involves the students cooperatively in teaching process (Mazur, 1997; Yadav, 2005). Mazur (1997) produced a manual containing a step-by-step guide for planning Peer Instruction lectures. This manual contains 44 Reading Quizzes, 243 Concept tests and 109 Conceptual Examination Questions. The data from ten years teaching with Peer Instruction indicate increased student mastery of both conceptual reasoning and quantitative physics problem-solving (Crouch & Mazur, 2001; Gok, 2012); Šestáková, 2013).

Active Learning Problem Sheets (the ALPS kit) developed by Van Heuvelen (1991) is a method of instruction in which students participate by interacting with their neighbours while answering conceptual questions and solving problems on the sheets. For helping students to develop physics concepts, use multiple representations, and develop problem solving techniques, sheets are used (Van Heuvelen, 1991).

For the considerable improvements in teaching effectiveness, there is strong need to develop good instructional materials, which support new curricula reforms. Much new instructional materials, which embody new reforms, are available. We have already discussed some of these instructional materials but other some more specific instructional materials are mentioned here including Mechanical Universe, Physics: Cinema Classics, text and a workbook, and some journals. Mechanical Universe is program in which D. Goodstein and R. Olenick produced videotapes on 28 topics of physics. From Project Physics and PSSC, Physics: Cinema Classics which is a set of double-sided videodiscs including film clips were developed (Salinger, 1991). Frederick Reif, a great cognitive scholar and trained physicist, prepared instructional materials dealing with mechanics consisting of a text and a workbook (Reif, 1995). Texts are designed to present the basic concepts of mechanics while workbooks are designed to engage students actively in their learning and to provide them with practice in applying systematic methods to solve various qualitative and quantitative mechanics problems (Reif, 1995). Some journals such as American Journal of Physics, Physics Today, The Physics Teacher, and Physics Education are also useful for secondary and university physics teachers.

Conclusions

In providing a brief historical overview of reforms in science curricula, the three waves of reform of science curricula emphasizing different considerations were discussed. Recently, efforts are being made to ensure an appropriate balance between different considerations. During the early reforms of physics curricula, the main focus was on teaching the basic disciplinary structure of physics. Little attention was paid on students' prior understanding of physics. In current physics curriculum developments, the recent findings from physics education research, cognitive psychology and education are taken into consideration. Several physics curricula which used new instructional methods involving more interactive-engagement, centering on problem solving, using cooperative learning, and using advance technology were discussed.

Recommendations

It is recommended for a physics curriculum to have an appropriate balance between the important considerations such as discipline, teachers, students and environment. Others include incorporation of strategies, resources, teaching, assessment and implementation in the design and development of a physics curriculum. The curriculum must emphasize on central ideas of physics and provide all students with an understanding of the relations between different parts of physics, as well as relations between physics and other fields of science. The science curriculum must also emphasize on the nature of science, scientific process and inquiry. Implementation strategies must be sufficiently flexible so that they are useful in school contexts. During implementation of curricula, care must be taken for the details of individuals, classroom and school environment. The institutions/departments wishing to develop research-based physics curriculum can use a coordinated program of research, curriculum development and instruction and may learn much from the experience of the other Physics Education

Groups. In designing and implementing of research-based physics curriculum, research efforts should explore collaborative, inquiry-based, interactive-engagement. Physics teachers should endeavor to develop learning lessons and activities that use cooperative learning methods. As teachers determine the curriculum in practice, they must feel that they belong to the curriculum. If a teacher is more committed to a change, Teachers will find more time to give to implementing that change if they are more committed. It is less likely to get intended student change if a curriculum change, change in instruction, and classroom is attempted without changes in assessment that are consistent with the curriculum change. Briefly, curriculum change without appropriate assessment is more probable impossible. Therefore, the efficient way of reforming physics education is to design tests and exams referring to the curriculum.

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