APPLICATION OF INNOVATIVE PEDAGOGIES TO ENHANCE THE TEACHING AND LEARNING OF CHEMISTRY

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Abstract

The Nigerian chemical education has been faced with many challenges. One of these challenges is the methodology of teaching used by chemistry teachers. The old methods of teaching like lecture and demonstration methods did not favor the 21st century learners in chemical science which as a result contributed significantly to the poor performance of chemical students. It is against this background that this paper critically discussed the concept of innovation in science education, the role of technology-based teaching and the weakness of lecture and demonstration methods to chemistry students. However, innovative teaching pedagogy such as Peer Instruction (PI), the use of Audio-Visual (AV) supplement, student-centered learning, improvisation and cooperative learning were briefly discussed as an alternative. Meanwhile, this paper recommended among others, the research studies using Peer Instruction (PI) and Cooperative Learning (CL) in Nigerian schools at all levels should be carried out in chemistry education to ascertain their effectiveness.

Keyword: innovation, science education, technology, innovative methods of teaching.

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Introduction

One of the prominent areas of education, which had attracted the attention of educationists through ages, is the process of making the teaching-learning situation easy for both teachers and the learners (Okoro, 2012).The classroom is the original cultivator of true learning and the green house that nurtures talent and creativity (Reachlvy, 2017). The dynamics between a teacher and students define the essence of a classroom. Okoro, (2012) and Reachlvy, (2017) however, opined that, a great teacher can transform the brick-and-mortar confinement and take students on a journey of pure learning, responding to their doubts and instilling an environment of curiosity and interactivity. The responsibility of the class teacher as noted by Aluko, (2008) is to help students attain maximum achievement in their learning tasks; thus, several competencies are expected from the teacher of which, the ability to use appropriate instructional strategies and innovations in teaching are considered to be crucial in achieving this goal. Etiubon, (2016) expressed that, the educational system is growing and innovations initiated globally makes it imperative for chemistry curriculum to be modified to meet present day chemistry challenges. Adikwu, (2008)

posits that, the chemistry curriculum should provide a new set of knowledge, skills and behaviors to make the practice of chemistry relevant to its learners and to include the teaching of chemistry in an innovative way.

The American Psychological Association in its report validates the importance of innovative teaching methods in science by saying, calls for reforms in the ways we teach science at all levels, and in all disciplines are widespread. The effectiveness of the changes being called for, employment of student-centered, active learning pedagogy, is now well supported by evidence. The relevant data have come from a number of different disciplines that include the learning sciences, cognitive psychology, and educational psychology. There is growing bodies of research within specific scientific teaching communities that supports and validates the new approaches to teaching that have been adopted (APA, 1989). Many educational institutions around the world are using modern available resources to enhance teaching and learning chemistry (Etiubon, 2016). The 21st century has in many ways focused mainly on change, such as what will be different? What will remain the same? How pervasive and long-lasting will changes are? These questions should always be at forefronts if the concept of innovation is to be discussed (Zeile & Jones, 2001). In recent years, there has been a widespread support around the world for reforming chemistry teaching in particular and science education in general (Eilks cited in Eilks & Hofstein, 2013).

New developments as it's involve building new learning experiences, an area where chemistry has a lot to benefit. New innovative technologies when adopted and integrated in teaching and learning of chemistry will greatly influence a better understanding of molecular structures, and an easy grasp of the relationship between structure and properties (Eilks & Byers, 2009). However, to build bridges between the learning that happens for students through classroom lectures and their individual study outside of class (Mahaffy, 2014; Chemistview, 2014) put together, all of these (technologies) as asserted by Mahaffy, (2014) are believed to support innovative teaching and learning, and similarly help students to engage deeply with chemistry content. The art of teaching is continuously evolving and advancing, making chemistry teachers re-evaluate their methods of instruction every year (Kristen *et al.*, 2017). For teachers, finding time to provide additional support to help students overcome weak areas can be very difficult. Using technology and innovations can serve as a way for students to build skills in weak subject areas which will make difficult times of learning fun an enjoyable, but most importantly it will help students build the confidence they need to succeed (Redish, 1997).

Meanwhile, Chemistry is thought to be a complex subject and can be very difficult to teach without the right resources; but educational technology and Innovation are the greatest resources believe to help students in learning science (Junker, 2018; Tarhan, 2008). While chemistry is a part of our everyday lives, students have found that chemistry can be difficult to understand; thus if a student is found to be weak in one area, additional support should be given to help that student strengthen their area of weakness so that they too can have an opportunity to realize their full potential (Tarhan, 2008). There are several attempts through which carefully planned use of instructional strategies and models can improve the status of chemistry teaching and learning. Despite all these efforts, students' performance in chemistry has remained persistently poor at the Senior Secondary Certificate Examination (SSCE). Prominent

factors contributing to the persistence of students' poor performance in chemistry are numerous of which lack of innovations in chemistry teaching and ineffective chemistry teaching methods are the measure attribute (Aluko, 2008 and Aluko, 2014).

Concept of Innovations in Educational Context

The ability to develop new ideas and innovation has become a priority for many organizations. Intense global competition and technological development have made innovation be a source of competitive advantage (Popa, 2009). Innovation is a "new idea, creative thoughts, and new imaginations in form of device or method" (Marriam-webster, 2010 mobile app version). Thus, the definition of innovation has been an area of interest both for researchers and different industries (Popa, 2009). It is however been perceived that, the way innovation has been defined within an organization will determine what activities will take place within the company or an institution and those that will be outsourced (Drucker in Popa, 2009). Scientists and industry used a different approach from many perspectives regarding the definition of innovation, including radical or incremental changes in products and processes (Popa, 2009). Innovation is the process of making lives better (Martins, 2004).

The core objective of teaching is passing an information or knowledge to the minds of the learners (Udu, 2018). Any method using computers or modifying the existing conventional chalk-talk method are accepted to be innovative if they ultimately serve the attainment of core objective of teaching (Okoye, 2012). Thus, in the conventional methods of teaching, the teacher controls the instructional process, the content is delivered to the entire class and the teacher tends to emphasize factual knowledge. In other words, the teacher delivers the lecture content and the students listen to the lecture. Thus, the learning mode tends to be passive and the learners play little part in their learning process (Aniodoh, 2001). In teaching of science, teachers are expected to have a good level of competence and mastery of the subjects before introducing it in the classroom; this will enhance effective teaching of the subjects (Udu, 2018). Teachers need to excite the interest and attitude of the students with regard to the subjects through their modes of teaching. The teachers are expected to be experts who have good exposure and experience in science. They are also expected to use innovative teaching strategies which will help to foster the adjustment of students, matching curricular offerings to levels of mental development, understand students' basic cognitive and social problems, making curricular specifications relevant, and motivate the students in the learning of the subjects (Nwachukwu, 2009).

Innovation in education as stressed by authors of many journals is a deliberate, systematic, novel, specific and persistent change in the system of a particular society, which is aimed at improving the system or creating a new one, for a more effective and efficient means of attending to the educational needs of the social group, in their social environment (Nwafor, 2007). Thus, Martins, (2004) considered innovation as that process that when incorporated in education especially in chemistry would enhance and make the teaching and learning easy and interesting. In their efforts to figure out the concept, Kirsi and Seppo, (1996) stated that Innovation in Education is a creative, new educational and innovational policy, a creative way to renew education, a creative solution, a creation of new educational culture, a new opening, and a new idea to overcome some problems in education. Kirsi and Seppo (1996) further express that innovation in education is a starting power, an idea that makes

things move. It is, however, necessary that our traditional methods of teaching chemistry in this fast changing era be modified; introduce innovations that will enhance the art of chemistry teaching at all levels of education. This has been an observation from different science tutors including (Udu, 2018). Similarly, Okoye, (2012) opined that a healthy system should tend towards inventing new procedures or process of teaching, move towards attaining new scientific goals, produce new kinds of products and become more rather than less.

The concept of innovations in science teaching is considered to be necessary in order to adopt innovations because of the needs and problems of the society always changes from time to time (Nwafor, 2007). Meanwhile, the system of education should therefore have to change in order to meet the changes of the society. The adoption of innovations in education offers the educational institutions the opportunity of making changes or improvement in the methodology of teaching. This is because it is when innovations are widely adopted that the reforms desired in the educational sector will be achieved. Therefore, in all discussion rained so far, it is generally accepted that, any move in education to accommodate new knowledge, remove obsolete ones and adopt multidisciplinary orientation is likely to be an innovation in education (Udu, 2018).

Incorporation of Innovative Pedagogies in the Teaching and Learning of Chemistry

There is no debating the fact that students need to be technologically savvy and educators are responsible for making students in colleges and their career ready for the 21st century. Similarly, with a wide range of applications available at our fingertips, educators need to determine which tools are the best aligned with content that will enhance the pedagogy for their students (O'Brein, 2018). Moreover, students have also culturally adapted to the world of smart phones where they can download an application to practice a chemistry skill, sketch and rotate molecules, makes mechanisms, etc. While there are many advantages of using such tools, the traditional paper and pencil method should not necessarily be dismissed (Williams & Pence, 2011).

Clifford cited in mcDonnell, (2013) wisely acknowledged that technology will not replace teachers, but teachers who use technology will replace the teachers who do not. Moreover, the use of technology has been widely found to increase student achievement and motivation, while the use of computer has been found to enhance meaningful chemistry learning and developed learning environment (Dori & Barak, 2000). Herein, the Integration of technology in secondary and high school education classroom allows students to build 21st century technology skills that they will be able to carry into any workforce and use for the rest of their life (Brown, *et al.*, 2018). According to U.S. Department of Education (2010), educators and technologists have published thousands of research studies and literature reviews aiming to discover how chemistry students learn best. Grossly lacking in research studies conducted is student learning outcomes on formative, summative, and state assessments as a result of using technology to teach.

The National Center for Education Statistics, NCES, (2002) published a report highlighting results of the study conducted by National Assessment of Educational

Progress (NAEP, 2000); in this report the National Center for Education Statistics took 8th grade student's science assessment scores and created a graphical representation showing test scores of students whose teacher used computer(s) for simulations or data analysis verses the student test scores of teachers who did not use computer for simulations or data analysis. The data revealed that the students whose teacher used computers for simulations and data analysis achieved significant higher test scores when compared to their peers whose teacher did not use computers. However, Onyia (2010) opined that the use of technology-based solutions for hands-on chemistry help engage student in chemistry and improve chemistry literacy. He further stressed that, the use of electronic learning systems like Owl, Mattering Chemistry, Smartwork, Wiley Plus are innovative, research-based online environment designed for both effective teaching and learning. They provide according to him the concept simulations, tutorials, visual exercises and problem-based homework which:

1. Improves student learning and grades,
2. Helps students visualize chemistry and improve problem-solving skills,
3. Allows students to work at their own pace until they master concepts and
4. Helps assess student progress.

The federal government of Nigeria has called for advancement to socioeconomic development in various ways, one of which is the introduction of information and communication technology (ICT) at all levels of education (Chinwe & Nnamdi, 2015). To actualize this, a lot of curriculum reforms were put in place. Therefore, the need for the implication of chemistry content using ICT cannot be overemphasized. The overall benefit is that the learning of chemical concepts will be enhanced; retention and transfer of knowledge could be assured (Chinwe & Nnamdi, 2015). To incorporate technology into lessons, teachers should consider the content at hands, the pedagogical method that best suits teaching the content and the technology that would aide or be the mechanism of instruction for a particular group of learners (O' Brein, 2018).

One of the simplest and most effective ways of incorporating technology into our teaching is to create podcasts and screen casts. A podcast (audio only) and screen cast (audio with video or screen capture) allows students to recover material in their own time at their own pace, and the useful resources for how these can be created in a chemistry context are readily available (Seery, 2013). These webcasts according to Seery, (2013) can be of two general types: either they recover what was provided in a class (substitution) or they provide extra material or explain in further detail something that was delivered in class (supplemental). Dalgarno, (2009) expressed that a simple Google search of chemistry video games will put students in a virtual world of molecules, molar masses, and complex equations. Virtual laboratories are one of the most effective ways for chemistry teachers to engage their students with active learning. Power Points instead of the conventional talk and chalk methods, teachers now include power point presentations in their classroom sessions to make it more interesting. They connect the computers to projectors to address a larger classroom and include interesting slides with diagrams and flow charts to make the teaching more interactive.

Common Methods of Teaching Chemistry

The teaching methods commonly used in science or by chemistry teachers are lecture and demonstration method. These methods shall be briefly discussed.

Lecture method

The importance of lecture as a method of disseminating information, facts, knowledge to audience date back to 14th century before it successfully introduced in to science subjects like chemistry, physics, biology etc. The word lecture from latin *lectus* meaning the action of reading or that which read, is an oral presentation intended to present information or teach people about a particular subject for example by university or college teacher (Wikipedia, ed, 24th September, 2019; Murphy, 2012). Lecture Method is a teaching process whereby the teacher verbally delivers a pre-planned body of knowledge to his students (Okoro, 2012). The teacher talks while the students listen and take note. Lecture method is often used to deliver a large amount of information to the students or audience in a short possible time (Berry, 2008). According to Bauum and Weinberger, (2014), lectures are designed to deliver new information to a large group of students. This method is known to be effective in dealing with a large class. However, it could also be used for a small class. Research indicates that this method dominates most of the tertiary institutions (Deslauriers, 2011).

Often the cornerstone of university teaching, lecture can be an effective method for communicating theories, ideas, and facts to students. Typically, a structured presentation, a lecture should be designed to include certain procedures in order to be effective procedures that research and expert lecturers have identified as essential to assist student learning (Murphy, 2012). There has been much debate as whether or not lecturing actually improves student learning in the classroom. Commonly cited disadvantages of lecture includes: placing students in a passive (rather than an active) role, encouraging one-way communication, requiring significant out-of-class time for students to engage with the material, and requiring the speaker to possess effective speaking skills (Murphy, 2012).

Research evidence also indicated that students' retention in a lecture-based science courses is weak. According to Bok (2006), an average student only retains 42% of what he or she learned after the end of the lecture and 20% one week later. Research also revealed that teaching method like the lecture method commonly used does not help the students to acquire sufficient functional understanding (Bernhard in Kola & Langenhoven, 2015). This was why Berry (2008) argued that lecture method lacks the effectiveness of an active learning approach. In the opinion of Fagen and Mazur (2003), lecture method causes the bad reading habit among the students.

Demonstration method

Demonstration method as the word implies it is a method employed by the teacher to show students how to manipulate equipment and apparatus and to solve numerical problems (Okoro, 2012). Through this method, various scientific procedures, processes and phenomenon are being shown to the students. However, this method

covers the draw back or limitations found in the lecture method in which much importance was paid to the teacher (Mallick, 2018 and McKee, 2007).

This is an important method for science teaching as science is not only a theoretical subject but have a considerable portion of practical work. Therefore, carrying out the successful demonstration activities in teaching process, a teacher can provide concrete experience to the students. Thus, this method can be implore by the science teacher when the number of students is greater than the teacher-student ration in the classroom and number of apparatus available in the laboratory is also insufficient (Okoro, 2012; Mallick, 2018). Demonstration method is a useful method of teaching because it improves students' understanding and retention (McKee, 2007). According to Al-Rawi (2013), the demonstration method is effective in teaching skills of using tools and laboratory experiment in chemistry. However, the time available to perform this demonstration is very limited in a classroom setting. Therefore, a demonstration often designed to allow students to make observations rather than through hands-on laboratory (McKee, 2007).

Innovative Pedagogies to Enhance the Teaching of Chemistry

The world wide exposition of teaching and learning chemistry is a clear turning point of the modern time. The rate at which chemistry is expanding to more different fields, calls for the introduction of innovations that will enhance its delivery in the classroom at secondary school and lecture rooms/halls in the universities. However, attention must be focused as asserted by Isiaka, (2014) on strengthening innovation capacity to transform chemistry and mathematics education is a way that needs an urgent assessment of the present state of a system and actionable recommendations. There are different teaching methods employed in science education in Nigerian tertiary institutions. Miles, (2015) asserted that it is expected of a teacher to implement a range of instructional strategies that will bring academic success to all the science students. For any method to be able to bring good result in the present age, it should be a method that promotes maximum social interaction. Social interaction among students, between teachers and students plays a crucial role in learning (Nguyen, 2012).

Peer Instruction

Peer Instruction (PI) is a research-based pedagogy for teaching large introductory science courses like chemistry (Fagen and Mazur, 2003). It is a method created to help make lectures more interactive and to get students intellectually engaged with what is going on. It has been tested in many science classes and found to be good for improving students' performance and used to identify student difficult areas. PI has also been used in different subjects in many countries (Kola & Langenhoven, 2015). Peer Instruction is still a new method of teaching for teachers in many countries because of its unique feature of *Concept Test.*

Peer Instruction as defined by Kola and Langenhoven, (2015) is an instructional strategy for engaging students during class through a structured questioning process that involves every student. PI provides a structured environment for students to voice their idea and resolve misunderstanding by talking with their peer (Gok, 2012). Peer Instruction involve students during class through activities that require each student to

apply the core concepts being presented, and then to explain those concepts to their fellow students. Unlike the common practice of asking informal questions during a traditional lecture, this typically engages only a few highly motivated students. PI incorporates a more structured questioning process that involves every student in the class (Kola & Langenhoven, 2015).The goal of PI is to transform the lecture environment so that it actively engages students and focuses their attention on underlying concepts (Kola & Langenhoven, 2015). Instead of teaching from the textbook or lecture notes, lectures consist of short presentations on the main points. Each followed by short conceptual questions called Concept Test, typically posed in a multiple-choice format, on the subject being discussed. According to Turpen and Finkelstein (2010) describes the process of PI as:

1. The question posed.
2. Students are given time to think.
3. Students record or report individual answers.
4. Neighboring students discussed their answers.
5. Students record or report revised answers.
6. Feedback to teacher: Tally of answers.
7. Explanation of the correct answers.

Audio-visual (AV) Supplements

The use of audio visual in industries has been extensive, as it has been effective in increasing productivity and retention rates, where research has shown that people remember 20% of what they see, 40% of what they see and hear, but about 75% of what they see and hear and do simultaneously (Lindstrom in EPM, 2012). Audio visual is now permeating the educational system as a tool for effective teaching and learning. Many educational institutions in India for instance have AV-equipped classrooms or venues to boost students' learning and understanding. Teachers explain difficult subject like Physics/Mathematics/Chemistry through graphical representation of complex equations with the help of smart-boards (Reachlvy, 2017). Subject teachers are leveraging AV facilities in interesting ways to trigger the class's curiosity through graphics, images, and puzzles, thereby driving them to think out-of-the-box. This method is best to teach science or chemistry at secondary. Above all, it satisfies a student's need to see, hear, and have a complete rasp of what they are learning (Reachlvy, 2017). Audio visual could be interpreted as a combination of data carriers, for example video, CD-ROM, floppy disks, Internet and software in which the possibility for an interactive approach is offered (EPM, 2012). Fetterman in EPM (2012) also viewed audio visual as those resources used for instruction that include one or more media such as graphics, video, animation, image and sound in addition to textual information.

Learner's Centered Method

As the center of all learning and teaching revolve around the student/learner, it would be unwise if the teaching method fails to recognize the central position of the student/learner and hence due attention paid (Udu, 2018). However, in this perspective of teaching chemistry as a science subject the student/learner is considered to be foremost and all his interests are therefore served. This type of teaching recognizes the needs, values and importance of the student/learner as the

center post of all teaching. This is a new perspective in the teaching of science which is different from the old/traditional method of teaching in which the teacher was seen as the most important person in the teaching and learning process. The student/learner-centered innovative methods consist of; planed discussion, advisory approach, panel discussion, small group discussion, seminar, debate, committee and group work, problem solving research, case study, etc (Ezeano, 2013). Several innovative teaching strategies which adopt student/learner centered method have been developed to bring about improvements in teaching and learning of science subjects in Nigerian schools (Samuel, 2007 and Neboh, 2012). The student/learner-centered strategies includes among others; the use of Analogy, Constructivism, Learning Activity Package, Concept Mapping, Cooperative Learning, Individualized Instruction, Computer-Aided Instructions, Programmed Instructions, Multimedia Instructional approach, Information and Communication Technology ICT (eg. Use of internet) approach, Science-Technology-Society (S-T-S) approach, etc (Udu, 2018).
Improvisation

Improvisation has been defined as intuition guiding action in a spontaneous way (Crossan & Sorrenti, 1997). According to Keefe, (2002); Improvisation is making the most of what you have and getting the most out of what you make. It is a conversational skill that, like other social and interactive skills, can be taught (Udu, 2018). Mills, cited in Uniproject, (2016) opines that improvisation is the production of a material of instruction that looks alike with the original design, or a replica of original design of any instructional material and by using relevant available local material. When improvisation is used in teaching chemistry students provide different answers throughout the discussion and the instructor does not evaluate any given answer, instead facilitates the improvisation among the students, with the goal of guiding them toward discovery of their own knowledge (Okoro, 2012 & Udu, 2018).
According to Uniproject, (2016); Chemistry is an exact science; the teaching of chemistry often requires creativity and improvisation. Teachers who are adapting at improvisation will likely to be more successful in imparting chemistry information to the novice chemists in their classes. Everyone gets to express themselves creatively, to play together, to have their ideas honored and to have their mistakes forgiven. Innovations in improvisation techniques, sometimes referred to as activities, exercises, or games, are tools that can be added to any existing set of science teaching strategies (Udu, 2018). It can increase students' awareness of problems and ideas fundamental to their intellectual development. Disciplined innovative improvisation provides instructors/educators with a way to conceptualize creative science teaching within curricular structures (Okoye, 2012).

Cooperative Learning

Cooperative learning is defined as a division for labour undertaken to solve a problem. For any given task, students divide the work and come together to present findings (Johnson and Johnson, 1992). Each student makes an individual contribution. Ziele and Jone, (2007) believed that cooperative learning is grounded in the belief that learning is most effective when students are actively involved in sharing ideas and working cooperatively to complete academic tasks. It is a teaching strategy according to Mehta and Kulshrestha, (2014) in which small teams, each with students of different levels of ability, use a variety of learning activities to improve their understanding of a subject. Cooperative learning is different from collaborative

learning. The basic difference is that collaboration is a philosophy of interaction and personal lifestyle where individuals are responsible for their actions, including learning, and respect the ability and contribution of their peers, whereas cooperation is a structure of interaction designed to facilitate the accomplishment of a specific end product or goal through people working together in groups (Panitz, 1997). Each member of a team is responsible not only for learning what is taught but also for helping teammates learn, thus creating an atmosphere of collective achievement.

The cooperative learning theory which plays an important role in the field of education recently aroused the interest of the experts in the field of science teaching in terms of designing a curriculum which enables the students to learn through cooperative effort, problem solving, and decision making (Mehta & Kulshrestha, 2014). In a cooperative classroom, the teacher assumes the role of facilitator and guide. Teacher becomes the manager and not the controller of the class. Students take the responsibility of their own learning. They ask questions, state problems, design activities, and discuss their results with others. Students are more positive about each other when they learn cooperatively than when they learn alone, competitively, or individualistically regardless of differences in ability, ethnic background, or being handicapped or not (Mehta and Kulshrestha, 2014 and Hermann, 2013).

Suggestions

The author suggested the following:

1. Many literatures reviewed by different authors confirmed the effectiveness of Peer Instruction and cooperative learning for improving conceptual and problem-solving skills of the students at different level of education. Therefore, this paper recommended that research studies using Peer Instruction (PI) and Cooperative Learning (CL) in Nigerian schools at all levels should be carried out in chemistry education to ascertain their effectiveness.
2. Secondary chemistry teachers must realize that the outcomes of their instructional methods must have direct impacts to chemistry workforce.
3. Chemistry or science teachers should be allowed to visit schools that are using innovative methods to observe new strategies and materials enhancing chemistry teaching.
4. Chemistry teachers should change and utilize the innovative methods in their lesson delivery to enhance students' active participation in the lesson for enhanced academic performance in chemistry.

Conclusion

The applications of innovations in the teaching of chemistry is a tool that when implemented right will enhance the students performance and improve the learner's active participation in chemistry. However, It is obvious that there are already known teaching pedagogies in chemistry education that actively engages students in the class such as the concept of cooperative learning, integrated innovative technology in chemistry teaching (e.g using power point, CHEMDRAW etc). Thus, PI and other innovative methods discussed in this review could be a better one. These pedagogies of teaching are innovative strategies or tools that empower both students and teachers.

Inco-operating innovation in chemistry teaching will also assist the learners to meet their basic needs, because they support students' preference for learning by doing. Meanwhile, the uses of innovative technologies are promising tools for instructors because they support teachers to engage students with hands-on inquiry learning.

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