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Toward Integrating Educational Technology Instructional Methods in Advanced Level Chemistry Teaching in Zimbabwe

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Abstract: *The article avers that the adoption and adaptation of educational technologies as an instructional method for Advanced level Chemistry teaching improves outcomes. The study conveniently settled for a former group A school in Zimbabwe's Midlands province as its case study. Premised on a qualitative research methodology and minimal quantification, a purposive sample of 30 students drawn from a population of 120 students in the sciences department, point out that, deploying educational technology tools in the learning process has desirable outcomes on a comparative basis with the traditionally preferred lecture method. It was established that it is both engaging and enriching to the learners, compared to the lecture method which prioritises pacing and covering the syllabus at the expense of knowledge comprehension. Instead of dichotomising theory and praxis, educational technology tools yoke both and this in turn yields desirable learning outcomes. Substantiating these viewpoints was data gathered from the lesson observations and the open-ended interview methods utilised as data gathering techniques. Therefore, the study recommends a paradigm shift from the preferred traditional lecture to an educational techno-centric pedagogy, in chemistry lesson delivery. If these micro teaching findings are transferred to a macro level, Chemistry excellent pass rates will be gradually obtained in Zimbabwe's secondary education sector.*

Keywords*: Chemistry teaching; Continuous assessment; Educational technology; Lesson delivery, Heritage Based Curriculum*

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1. Introduction

The Confucius dictum, 'I hear I forget, I see I remember, I do I understand' aptly exemplifies the need for a robust utilisation of educational technology for Advanced level chemistry learners in their quest to attain what this article considers excellent or high quality passes (grade A and B). The article posits that, educational technologies such as Phet simulation and Virtual chemistry laboratory are functional educational technological tools to the A level Chemistry learner in Zimbabwe. As a preliminary matter, Advanced level is a two-year course normally taken by learners who have passed their ordinary level certificate. The first year of the course is referred to as lower sixth level whereas the last year is the upper sixth level. Educational technology is defined in several ways by many educational technologists. It refers to, "an educational technology that deliberately includes pedagogies among the technologies that it orchestrates," (Dron 2022, p. 6). This adopted definition revolves around the process of facilitating learning hence it has been used in this respective article to demonstrate how technology can solve pedagogical problems and in turn lead to the realisation of set objectives.

Unpacking the American experience, Pucket (2013) holds that technology is becoming more prevalent in the American classroom since students are becoming very techno-savvy as they utilise computer programs, iPads, and applications in an unprecedented level. This American experience suggests that, if educational technologies are responsibly managed, desired goals can be easily attained. Such insights were critical in the understanding and utilisation of technologies in the learning of chemistry which is a subject construed to be confined to laboratories rather than IT tools.

The UNESCO GEM Report of 2023 also acknowledges that there are contradictions on how the role of technology is perceived in education sector. While the appropriate use of technology can offer solutions issues such as access, equity and inclusion are a challenge especially in developing countries and the Global South in particular. Considering many school environments, regulated technology can be deployed for educational purposes as this cut costs.

Seuyong et al (2023) also acknowledges that digital connectivity is a game changer in the provision of services such as economic growth, innovation, and job creation, among others. The lagging in terms of internet access, computer hardware and mobile phones calls for an improvement of the digital infrastructure in third world countries where low-income groups dominate. The education sector, as this paper notes, is not an exception since it is equally affected in its endeavour to provide quality education.

Ezumah (2020) also explains the challenges that impact the successful adoption of educational technology on the African continent. These are stated as varying from individual to community, religio-cultural, infrastructural, policies, inadequate training, or absolutely lack of training. It further states that obstacles such as costs, lack of, or inadequate training for teachers to fully implement the technology in classrooms, lack of infrastructure and power supply faced by African countries in educational technology adoption can be ameliorated.

In Zimbabwe, the Presidential computerisation scheme, among other stakeholders as Konyana and Konyana (2013) posit, has provided computer hardware to improve rural learners' access to modern technologies. They argue that the gap between a rural and urban learner in terms of access to ICT is yawning since most of these schools' donated hardware had not been capacitated to fully utilise the recent technology for the benefit of students, teachers, and the community. As a result, most of the gadgets have been lying idle in classrooms due to lack of both proper infrastructural facilities such as computer laboratories and electricity as well as lack of trained ICT teachers.

Be that as it may, in this article, we note that while developed countries have succeeded to implement educational technologies, in Zimbabwe there is little or no engagement because of varying factors albeit its high potential on improving pass rates in science subjects such as chemistry, which are lowly resourced in terms of chemicals and equipment. Such a subject can utilise educational technology tools such as Phet cumulation and other web related applications for improved pass rates. Therefore, the teaching processes of a learning area such as chemistry, the article holds, has a strong bearing on the outcomes in the very respective subject. Be that as it may, Chemistry, as a learning area occupies a critical space in the Zimbabwean education curriculum in general as evidenced by Chitate (2016, p. 27) who gives an exposition of the prominence given to science subjects through innovation curicula:

> In March 2012, for example, the Government of Zimbabwe (GoZ) pronounced the 'Second Science, Technology and Innovation Policy' framework, which provided the two Ministries of Primary and Secondary Education and Higher and Tertiary Education, Science and Technology Development with the opportunity to implement the relevant spellings out of that policy document. The former launched an update review of the national curriculum, in 2014, which culminated, in the crafting of the Zimbabwe Education Blueprint (2015-2022). That education-design plan has many facets. Chief among them is a deliberate emphasis on the teaching of Science, Technology, Engineering and Mathematics, subjects that are now known popularly by the acronym 'STEM.' Classroom instruction, in those disciplines is meant to empower students with the cutting-edge skills that should see them participate actively, in both the local and global economies. The latter Ministry has rolled out the new STEM curriculum at the Advanced level, in January 2016.

Considering the above explained government effort, the current Heritage Based Curriculum Framework 2025 – 2030 (henceforth HBC) continues to pursue this STEM thrust, which Chemistry is an element of, since solutions to hunger, poverty, diseases and medicine among others can only be solved, particularly through STEM since countries develop based on their intellectual capacity, property and the human capital base. The Chemistry learners are part and parcel of the future producers of patentable cutting-edge intellectual property. It is usually pursued by outstanding science learners whose career paths among others include pharmacologist, nanotechnologists, toxicologist, chemical engineer, materials engineer, forensic chemist, food technologist and medical doctor among others. Based on the above expatiated functional nature of this learning area, this study is of the view that it is significant to devote its attention to how teaching and learning of such a critical subject can be improved against the fact that, though grades A, B, C, D, E are considered as passes by the Zimbabwe School Examination Council (ZIMSEC), for effective penetration and absorption into Higher

Education Institutions (HEI) such as universities for programmes related to the aforementioned careers, a student with an A or B grade stands a better chance of being enrolled to pursue such courses, provided the other subjects such as Maths and Biology or / and Physics have been graded with As, as preliminary findings posits. This is against the reality that the competition is tough and there is a regulated number of students per intake. Considering the current job market trends and demand realities, grades C,D,E though considered passes by the examination body, are weak passes that are likely to affect the career choices of the high school leaver.

In January (2020), the Zimbabwe Schools Examination Council (ZIMSEC), through its then Chairman, Professor E. Mwenje, expressed concern over the failure rate or low pass rate for learners who took on science subjects at Advanced level science subjects as it was announcing the release of the November session. The Examination Board chairman stated that of the 17,749 candidates who registered to write Chemistry, Physics, Biology and Mathematics, only 5,610 passed two or more subjects with Grade E or better, representing a 31,6 percent pass rate. Below are his remarks verbatim:

> The Ministry of Primary and Secondary Education needs to closely look into this area...there could be a number of factors which need further interrogation that could be contributing to this poor performance. We need to closely look at each subject because these are the second results from the recently introduced competency-based curriculum. The other contributing factor could be that science subjects require a lot of input and equipment which most schools do not possess. (ZIMSEC Sciences' Chief examiner's Report for November/December 2020 Session)

Against this backdrop, this article is of the view that, Chemistry learners need to maximise their chances of being within the 24% of students who usually make it into the A or B grade every year. In light of the foregoing, this article is of the view that the 76% learners who find it difficult to make it into the A or B grade every year, can be scaffolded from these weak passes – C,D,E so as to maximise the satisfactory prospects of the combination they settled for – usually Maths/Physics and or Biology among Chemistry. Obtaining and realised as the missing link in this matrix has been the yawning gap in the delivery of chemistry lessons at Advanced level. Unlike the former competency-based curriculum, the newly introduced Heritage Based Curriculum Framework (HBC) for the period 2025 – 2030 must prioritise educational technology through the utilisation of virtual chemistry laboratories and Phet simulations as part and parcel of the instructional method.

As posited by Lombo and Subban (2024), Barrett et al (2019), Mgimba and Mwila (2022), John and Aliyu (2024) low resourced physical infrastructure such as laboratories has a direct impact in the teaching and learning processes and the quality of education. The teaching practice, carried out at the aforementioned school during the first term of the school calendar (January to April) informs the study.

2. Literature Review

Educational technology as a teaching method utilises the existing information, communication and technology (ICT) infrastructure in the immediate environment. The availability of resource person and competent personnel is also key to implementing educational technology pedagogies in the school environment even though HBC frameworks recognise its significance.

The study utilises the conceptual framework attributed to the ancient Chinese philosopher, Confucius as it relates to learning. It is aptly expressed in the philosophy, 'I hear I forget, I see I remember, I do I understand.' It perfectly fits to this study since it underscores the value of learning by seeing and doing. It does not prioritise invoking the sense of hearing, which is very dominant in lecture modes of teaching, since it fosters rote learning. In this study, its viewpoints, we assert resonates with Phet simulations and virtual chemistry laboratory applications that were deployed during micro teaching of chemistry learners as it improved teaching. This resonates with the constructivists' perspectives on student centred education.

Dron's (2021) theoretical study explains what educational technology is and how it also works. It posits that teachers are not just users of technologies but also co-participants in the teaching and learning process when utilising educational technologies. As further posited, this is due to the fact that technologies leave gaps that sometimes must be filled by germane orchestrations. Referred to as 'participative orchestration,' the teacher and the learner all become involved. It concludes that, in the light of this exposition, all learners and teachers are technologists.

Johnson et al (2016) assert that technology, in the United Kingdom, is the strongest factor shaping the educational landscape. This is characterised by the evident use of hardware such as tablets, computers, and laptops. However, the findings posit that there is needed to implement programmes that improve computer literacy for both teachers and learners since they find smooth and effective integration of new educational technologies challenging. Elaborating further, they advance that the challenges range from the acquisition of modern technology equipment and incorporating new educational tools is perennial. They recommend that professional development be continuously afforded through teacher training.

Similarly to Johnson et al (2016), the impact of modern technology on Chinese education are also explored by Minjie (2021). The study holds that the rapid development of the internet and modern technology is

becoming rapid and be that as it may, when technology enters the classroom, it becomes a smart classroom. The COVID 19 period as the findings of the study posits, facilitated the adoption of online modes of learning thereby making teachers roles transform in this information age.

Mukuni (2019) conducted a study on the challenges of digital infrastructure in Africa philosophising on this possibility as something that brings hope or confusion on the continent. The study acknowledges that technology-based learning is of late popular in Africa due to the advent of pandemics such as COVID-19. This as the study further argues presents an opportunity for access to education. In his study the researcher utilised more of desktop research as it advances that significant stride in relation to ICT advancements in the post 2000 era provides an opportune environment for exploiting digital pedagogies.

Butcher's (2003) study also gives an overview revolves around the technological infrastructure and use of ICT in education in Africa. The thrust in the study is on distance education and open learning as it takes place in sub-Saharan Africa. It posits that there is a dearth of information on ICT and education in Africa. This gap the study argues, affects decision making since in relation to educational reforms since this has to be guided by research and analytical work. Furthermore, the findings of the study acknowledge the role of 'older' technologies such as radio and technology and how they can be used in the context of emerging teaching technologies.

Agyei (2020) examines the impact of educational technology initiatives on student learning outcomes. Utilising a project *Africa Digital Schools ICT-intervention* which was carried out in six sub-Saharan African countries, including Zimbabwe, it found out that there is lack of supportive environment to buttress project ideas to school levels. These findings were based on a sample of 542 students and data was solicited through an online survey evaluation whereby semi structured questionnaires were deployed. The study recommended that, an enabling environment for the use of ICT related teaching has to be provided for countries of similar contexts.

In the Zimbabwean context Nherera and Mukora (2024) unravel how the higher education system strives to digitalise as it aspires to attain the national vision of becoming an upper middle-income economy by 2030. Utilising a desktop review of literature, the study examines the policy framework that was put in place in Higher and Tertiary education. The findings point out that many institutions have adopted externally developed digitalisation models without adequately adapting them to local circumstances hence it recommends the need to develop own educational technologies.

Also, Dzinotyiwei and Taddese (2020) carried out a survey whereby focus was on exploring factors that hinder or promote the use of technology in education. These factors include the policy or vision for EdTech, institutional capacity, private-sector partnerships, and the digital infrastructure. Though not very comprehensive in detail, their findings are pertinent vis-a-vis prospects and challenges in Zimbabwe's evolving educational sector.

What is obtaining from the literature reviewed is the fact that in Africa, as compared to the Global North nations, educational technologies are rarely deployed because there is a lot of challenges ranging from the lack of ICT infrastructure and techno-savvy educators. It is into the Midlands province case study where both the infrastructure and the ICT competent Chemistry educators are present that the study shifts its focus to, in an endeavour to analyse and discuss the results.

3. Methodology

3.1 Design

The study is hinged on a purely qualitative (descriptive) research methodology since chemistry pedagogy issues entirely manifest in a classroom setting. However minimum quantification is infused in the discussion and analysis since these findings are targeted at various stakeholders who are mostly administrators and non-chemistry specialists. According to Burns & Grove (2001), research methodology is defined as the total strategy, from the identification of the problem to the final plans for data gathering and analysis. The qualitative approach was utilised because of its emphasis on the dynamic, holistic and efforts to capture experiences in their entirety and within the context of those experiencing them as Polit & Beck (2004) posit.

The selected primary case and source of data is a conveniently selected High School in the Midlands province. On case studies, Coombs (2022, p. 1) holds that:

> A case study is a methodological research approach used to generate an in-depth understanding of a contemporary issue or phenomenon in a bounded system. Case study research requires in-depth investigation conducted into an individual, group, or event to gain an understanding of a real-life phenomenon. It is often used in the social sciences and humanities to explore complex issues and to provide insights into specific phenomena or situations.

In this ongoing article, the case study was utilsed in the form of a macro school that has an enrolment or population of 1800 learners. The teaching and learning process, due to the insufficient number of classrooms, is done by splitting study hours. This results in two learning sessions whereby some students attend in the morning and others come in the afternoon. A convenient sample

of 30 Advanced level learners was drawn for this action research. The setting is Gweru District, precisely the dormitory high-density suburbs in the Midlands province of Zimbabwe. Zimbabwe is a southern African nation found in the Southern African Development Community (SADC) region. The metropolitan school was purposively selected and utilised on the basis that one of the principal investigators or researchers has been a resident educator and Head of Sciences Department at the very same school for more than a decade. With their ethical clearance and consent letter, this enabled him to solicit data from established chemistry teachers and their respective mentees who were on teaching practice from one of the state universities.

3.2 Data Collection Instruments

Oral open-ended interviews with experienced Chemistry teachers (n=1) and their mentees (n=2) were conducted. Weller et al (2018) is of the view that,

> Open-ended questions are used alone or in combination with other interviewing techniques to explore topics in depth, to understand processes, and to identify potential causes of observed correlations. Open-ended questions may produce lists, short answers, or lengthy narratives...

It is considering the above that the current study settled for this data gathering technique so as to maximise the richness of information. The data gathered was recorded utilising voice recorders after seeking respondents' consent. This was then transcribed into text for analysis. A thematic analysis generated critical and relevant to this study. In situ lesson observations were also carried out on two different topics in the two different classes that were under study. Document analysis of books, exercises and tests were done. The morning class, referred to as Class X, had 15 students (n=15) while the afternoon class, Class Y, had 15 students (n=15). The first observation revolved around mole concept whereas the second was on empirical and molecular formulas. These in class lesson observations afforded the researchers to get in depth insights on how educational technology is handy in the teaching and learning vis-a-vis improvement of results in the learning area of Chemistry in Class X on a comparative basis with Class Y which deployed the laboratory based conventional lecture method. The utilised web applications that were deployed for class X were Phet simulations and Virtual Chemistry laboratory. The experienced teacher and the mentee logged in and downloaded the videos prior to the commencement of the lectures in both instances whereas in Class Y, the conventional low resourced laboratory was utilised.

4. Results and Discussion

The thrust of the research endeavour has been on comparatively investigating the impact of utilising Phet simulations and the Virtual Chemistry Lab applications in the teaching and learning of Advanced level Chemistry with the goal of improving the quality of passes in the respective learning area (subject). Research respondents that were involved in this investigation, as mentioned in the methodology included a substantive chemistry teacher and two trainee teachers that were under his supervision during micro teaching of the first school calendar term that began from the 14 of January 2025 to the 10th of April 2025. Lesson observations were carried out in class X and class Y with particular interest on how the utilisation of Phet simulations and the Virtual Chemistry Lab applications in class X improved performance. In class Y, focus was on how the traditional lecture method and traditional laboratory teaching methods impact on excellent or quality grades. During the lesson observations crits were written in narrative form and documents such as records of marks were used to extract data, especially weekly exercises and monthly tests. Data is from these class visits observations and perused documents. The table below illustrates the score ranges that were obtained utilising the two different methodologies in the teaching of two covered topics, namely mole concept and empirical and molecular formulas during the period.

Table 1: Distribution of Advanced level Chemistry students' performance in Class X (Educational Technology / virtual lab) method) and Class Y (Lecture based-laboratory method) across assessments. Each value represents the number of students falling within a particular score category.

Tests & Exercises	Date	Topic	CLASS X (n=15)					CLASS Y (n=15)				
			A (70–100)	B (60-69)	C (50–59)	D (45–49)	E (40–44)	A (70–100)	B (60–69)	C (50–59)	D (45–49)	E (40–44)
Weekly Exercise 1	24 / 01 / 25	Mole concept	11	3	1	-	-	5	1	7	2	-
Weekly Exercise 2	31 / 01 / 25	Mole concept	12	2	1	-	-	4	4	6	1	-
Monthly Test 1	07 / 02 / 25	Mole concept	13	1	1	-	-	4	3	7	1	-
Weekly Exercise 1	14 / 02 / 25	Empirical and molecular formulas	13	1	1	-	-	5	3	6	1	-
Weekly Exercise 2	21 / 02 / 25	Empirical and molecular formulas	14	1	0	-	-	5	3	6	1	-
Monthly Test 2	28 / 02 / 25	Empirical and molecular formulas	13	2	0	-	-	5	4	4	2	-

The presented data in the above table reflects those weekly exercises written in the month of January, Class X had more learners obtaining quality passes compared to Class B. The mole concept topic that was taught using web-based application such as Phet simulations and virtual chemistry laboratory produced 11 A grade passes for the first weekly exercise, 3 B grade passes. These are excellent passes for prospective learners who have ambitions to pursue medicine at the university level. Only one weak pass, a C grade, was realised in the very same first week. This trend also continued in the second week with 12 learners and 2 learners in the A and B grade, respectively. The very same learner obtained a C grade pass, which is a weak pass by career prospects standards since the social record that was observed by the principal researcher says that the learner has career ambitions of becoming a medical doctor. With these trends that kept on manifesting in the monthly test of January, the learner is likely to face a challenge if this kind of performance spills into the upper Sixth level. While educational technology, through downloaded simulations and web-based applications proved effective, the traditional lecture method yielded less satisfactory results considering the fact that, the respective learners also have ambitions of being medical doctors.

In all their weekly tests written in January, only 8 learners had excellent passes while the other 7 are getting weak passes. Though a 100% pass rate was obtained in the monthly test of January in both classes, this study realised that in terms of excellent or quality pass rate that resonates well with the learners' ambition is at 93.33% since in the A and B grade, there are 14 learners. Only 1 who represents 6.66% has a weak pass. In Class Y, excellent passes for the month of January constitute 46.66% while 53.33% are weak passes that poses a challenge to university education vis-a-vis the medical pharmacology field they aspire to pursue.

Be that as it may, in an interview the respective trainee teacher for these students posited insightful opinions. The chemistry trainee teacher for Class Y said:

> The lecture method is highly effective only in making sure that the syllabus is covered on paper, for schemes of work evaluation. Out of the 24 topics that are expected to be covered over a period of two years, pacing and dictating notes becomes easy. However, the challenge is on the depth of learning detail that the learner is subjected too since much is done by the teacher, with the student being more of an observer and notes taker. In short, I am saying this method is not teacher centred hence there is need to resort to current educational technologies in the teaching of Western scientism.

Emanating from the teachers above remarks and what was observed during class visits by the principal investigator, there is less change that takes place in the teaching and learning of chemistry at advanced level, if the traditional laboratory-based lecturer method is deployed. This is largely because the teacher is involved more in the teaching and learning process more than the students themselves. The teacher becomes more of an active participant who is relegated to the periphery when assessment times comes, both in theory and titration. This is also buttressed by American studies carried out by Yesgat et al (2023) who hold that incorporating technology increases learner's achievement and retention, hence there is need for the African experience to adopt, adjust and adapt to chemistry pedagogies in the form of educational technologies and applications. This is feasible since, of recent in Zimbabwe many schools are networked to the internet due to the advent of Space based Starlink internet services.

The month of February, in terms of weekly exercises, Class X had 13 and 15 excellent passes in week 1 and 2, respectively. There is only 1 week pass in this empirical and molecular formulas topic that was taught via Phet simulations. The web-based application proved handy in making sure that a 100% excellent (A and B grade) pass rate was attained in the February monthly test. A contradistinction with Class Y, which utilised the traditional laboratory-based lecture method reflects that quality or strong passes that opens an avenue for a career in medicine or pharmacology were in between 53.33 and 60%. The yawning gap between these two classes as the H.O.D notes can best be construed within the utilised teaching methods deployed in this micro teaching endeavour. In terms of the final monthly test, Class Y's 60% quality pass rate is a bit distant compared to the 100% attained in Class X. The chemistry trainee teacher for Class X had this to say:

> Educational technologies, especially web-based applications are the game changer in the teaching of chemistry since in the third world we do lack financial resources to buy chemicals due to constrained budgets. These technologies are easy to use, and they improve students' learning outcomes. Succinctly put, they help in the moulding of the 21st century learner since education is both a process and a product. The human capital base in these critical sectors such as health will be improved if the relevant stakeholder embraces technological changes in the learning of not only chemistry but other science and technology-based subjects. In my class learning was very engaging, transactional, and dialoguing.

From the above sentiments, engaging educational technology tools available on the internet improves the teaching and learning of chemistry. The comparative study between the two classes that recruited students based on their equal ordinary level results has proved that. Learning with technological advancement is engaging and motivating while utilising obsolete equipment and the traditional method is uninspiring to the inquisitive learner. Vigorously combining internet and education seems to be the way forward in the teaching of chemistry at advanced level, for the attainment of excellent and quality passes that position learners into their prospective career paths such as medicine and pharmacology among others.

5. Conclusion and Recommendations

5.1 Conclusion

The study has established that, there is need for a paradigm shift in relation to the teaching methodologies to be deployed in the teaching of advanced level Chemistry. The traditional laboratory-based lecture method approaches are lagging in as far as easily found web-based applications such as Phet simulation and virtual chemistry laboratory are concerned. This was realised in action research that was carried out in line with the HBC at a school in the Midlands province in Zimbabwe. Based on these findings, the research concluded that the yawning gap that was realised in terms of outcomes between the two classes that were the focus of the study exposed that chemistry attains weak passes because of the traditionally deployed pedagogy. There is need for relevant stakeholders at every level to make a step towards educational technologies in the teaching of advanced level chemistry if strong passes are to be attained. This will in turn impact on the prospective career paths that learners want to pursue after high school education

5.2 Recommendations

1. In the light of the above context-based insights, the study proffers actionable recommendations that the Phet simulations and virtual chemistry laboratory web-based applications among others must be adopted and utilised in the teaching of chemistry at advanced level. This must be engaged as part of internet education with the goal of attaining excellent and quality passes (A or B) and providing new answers to old problems.

2. Furthermore, substantive teachers need to adapt or be retrained to the new educational technologies instructional method related to chemistry teaching in particular, and other science subjects in general as a way of getting rid of supposedly immutable approaches such as the lecture method.

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