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Development of an Intertextual E-Module on Intermolecular Forces with Potential to Improve Students' Concept Mastery and Critical Thinking Skills

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Abstract: This study aims to develop an intertextual-based e-module on the concept of intermolecular forces that has the potential to improve students' conceptual mastery and critical thinking skills. The research was conducted using the ADDIE model, which concluding at the development stage. The e-module was designed by integrating multiple chemical representations (macroscopic, submicroscopic, and symbolic) to enable students to master the concept comprehensively. In addition, the e-module was developed based on critical thinking indicators. The results showed that the e-module had characteristics of being self-instructional, self-contained, stand-alone, adaptive, user-friendly, consistent, multimedia-integrated, intertextual-based, and attentive to learning principles. The developed e-module was tested for feasibility by media experts, language experts, subject matter experts, and instructional method experts. The feasibility test results indicated that the e-module was declared feasible with some suggestions for improvement. The suggestions and feedback from the experts were used to revise the product design. Thus, an intertextual-based e-module on the concept of intermolecular forces was obtained, which has the potential to improve students' concept mastery and critical thinking skills.

Keywords: Concept Mastery; Critical Thinking Skills; E-module; Intermolecular Forces; Intertextual

Introduction

One of the chemistry concepts frequently perceived as challenging and leads to misconceptions for student is intermolecular forces. Previous studies conducted by Gudyanga & Madambi (2014), Vladusic, Bucat, & Ozic (2016), Islami, Suryaningsih, & Bahriah (2018), Sukib & Mutiah (2020), Rahayu & Fitriza (2021), Ma'rufah, Effendy, & Wonorahardjo (2022), Ulfah, Erlina, Pratiwiningrum, Wafiq, & Juahir (2024), Lahlali, Chafiq, Radid, Atibi, el Kababi, Srour, & Moundy (2023), and Widarti, Nuriyanti, Sari, Wiyarsi, Yatimah, & Rokhim (2024) have consistently found that students still struggle to distinguish between intermolecular and intramolecular forces. Furthermore, misconceptions persist regarding London dispersion forces, dipole-dipole interactions, ion-dipole interactions, and hydrogen bonding. Supporting these findings, interviews with chemistry teachers confirm that students continue to encounter difficulties and misconceptions concerning intermolecular force concepts. Such misconceptions often arise from an incomplete understanding of the concepts as a whole (Puspitasari, Reza, Bachtiar, & Prayitno, 2019). Untreated misconceptions hinder students' ability to understand new concepts and significantly impact their learning outcomes (Sa'diyah & Sukarmin, 2021). Therefore, it is imperative to promptly addres student misconceptions (Kumalaningtias & Sukarmin, 2019).

Conceptual mastery is a crucial aspect that warrants significant attention within the learning process (Sastrika, Sadia, & Muderawan, 2013). Students need to master one concept to facilitate the understanding of subsequent concepts (Puspitasari et al., 2019), allowing

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them to apply established concepts to new ones (Mangawe, Pikoli, Mohamad, Laliyo, & Kurniawati, 2025). To achieve a comprehensive mastery of chemical concepts, students must be capable of representing chemical phenomena across three levels of representation: macroscopic, submicroscopic, and symbolic (Johnstone, 1993). These representations serve as a means to express phenomena, objects, events, abstract concepts, ideas, processes, mechanisms, and even systems (Wu, Krajcik, & Soloway, 2001), which are subsequently reflected through an understanding of phenomena and the interconnectedness of representations across levels in chemistry, viewed as intertextual relationships (Wu, 2003). According to Ryu, Nardo, & Wu (2018), intertextual relationships are considered in helping students to construct and identify abstract chemical concepts within existing phenomena. Several studies (Utami, Suma, & Karyasa, 2024; Irsyad & Linuwih, 2018; Taslidere, 2013) suggest that intertextual-based learning can minimize student misconceptions and significantly enhance their conceptual mastery.

In addition to concept mastery, students must be equipped with other competencies, such as critical thinking skills (Septikasari & Frasandy, 2018). Without the ability to think critically, students tend to passively accept information without re-evaluating or selecting the information they receive (Setiana, 2019; Wijayanti, Prayitno, & Sunarto, 2016). Conversely, in the context of chemistry education, critical thinking skills are essential competencies that should develop and master, enabling them to analyze various phenomena or issues that arise in daily life (Sastrika et al., 2013). Students who possess these skills find it easier to comprehend the relationships between concepts, effectively analyze chemical problems, and determine the interconnections between various factors (Nugraha, Rosdianto, & Sulistri, 2022; Akihary, Lestuny, & Apituley, 2024; Napitupulu, Siahaan, & Akhsan, 2024; Amanda, Sumitro, Lestari, & Ibrohim, 2022).

Despite its importance, learning resources available in schools often provide only superficial explanations and are predominantly dominated by theoretical generalizations. In contrast, students require an objective, concrete, and rational approach to learning to achieve deep comprehension (Ulfa, Ali, & Khaeruddin, 2025). Furthermore, the inadequate visualization of submicroscopic and symbolic aspects, coupled with a lack of effective instructional media, significantly contributes to the suboptimal conceptual mastery and critical thinking skills observed among students (Sailendra, Erlina, Ulfah, Enawaty, & Nizam, 2025; Rahmawati, Dianhar, & Arifin, 2021).

Interactive pedagogical innovations leveraging various digital platforms offer a viable solution to these challenges. Interactive multimedia, specifically, facilitates students in correlating and applying chemical concepts to real-world contexts (Surachman, Muntari, & Savalas, 2015). Furthermore, the implementation of interactive multimedia, such as e-modules, is recognized for its ability to foster effective and engaging learning environments (Hendrawensi, Hidayati, Yeni, & Zurwina, 2024). Such tools simultaneously enhance student motivation (Damanik & Nugraha, 2023), conceptual mastery (Umar, Baturante, Rahman, & Ahmar, 2023), and critical thinking skills (Kelana, Irawan, Karubaba, Sahar, & Daullu, 2025).

In Chemistry Education, several studies have developed e-modules that can be used in the learning process. Azizah, Wiji, & Yuliani (2025) designed an e-module based on an intertextual approach and the 5E model for corrosion concepts. However, the developed module was not intended to enhance critical thinking skills. In a similar vein, Shobri, Surif, Ibrahium, Nursiwan, & Bunyamin (2021) developed an e-module using the 5E model to improve students' critical thinking skills, though it did not address the concept of intermolecular forces. Rasyid (2020) developed an intermolecular force e-module, yet it was not structured around an intertextual approach and did not explicitly target the improvement of critical thinking skills. Likewise, the e-module developed by Herman (n.d.) was not based on an intertextual approach and did not optimally integrate the three levels of chemical representation. Consequently, a crucial gap remains, nearly all existing e-modules fail to interconnect the three levels of chemical representation. In contrast, difficulties in chemistry learning persist because students struggle to relate everyday phenomena to molecular and symbolic explanations.

Based on the discussion, although many e-modules have been developed for chemistry education, research focused on developing an intertextual-based e-module to enhance both the conceptual mastery of intermolecular forces and critical thinking skills remains non-existent. For this reason, this study was conducted to develop an intertextual-based e-module on the concept of intermolecular forces with the potential to improve students' concept mastery and critical thinking skills. This research resulted in a valid e-module prototype, refined through suggestions and feedback from experts in chemistry, education, and instructional media.

Method

The research employed the Research and Development (R&D) method. The ADDIE instructional model consists of five stages (Analyze, Design, Development, Implementation, and Evaluation). However, this study was limited to the development stage. The ADDIE model was selected due to its simple presentation, which allows for easier implementation and a structured sequence. Furthermore, the inclusion of a validation stage ensures the production of a more refined final draft (Syafriah & Bachri, 2017).

Figure 1. The Process of ADDIE

The analysis stage is conducted to identify the performance gaps, resulting in an analysis summary (Branch, 2009). This phase involves a comprehensive review encompassing needs assessment, curriculum analysis, analysis of students' persistent difficulties and misconceptions in chemistry, concepts analysis, evaluation and analysis of students' concept mastery and critical thinking skills, and analysis of existing chemistry e-modules.

The design stage aims to ensure the desired performance and appropriate testing methods, resulting in a design brief (Branch, 2009). This stage involves drafting the e-module outline, the preparation of the initial e-module product design as a plan to integrate chemical multiple representations into the e-module, the construction of formative and summative questions to be used in the e-module, and the development of feasibility instruments.

The development stage focuses on producing and validating the required learning resources. This phase includes selecting or developing supporting media tailored to the e-module's requirements and constructing an intertextual-based e-module on intermolecular forces. The product then undergoes validation by experts. A revision process is conducted, incorporating suggestions and feedback provided by the experts to refine the module.

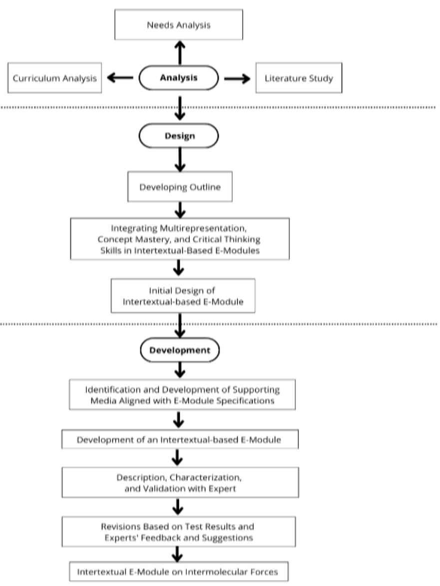


Figure 2. Research Development Procedure

The validation results from experts are converted into quantitative data using a Guttman scale, which consists of only two intervals, 'Feasible-Not Feasible'. The use of the Guttman scale aims to obtain firm answers regarding the structural format or components that must be present in the developed e-module (Meliana, Herlina, Suripah, & Dahlia, 2022). The Guttman scale specifications can be seen in Table 1.

Table 1. Guttman scale determination rules

Description	Score
Feasible	1
Not Feasible	0

Subsequently, to measure the validity level based on the Guttman scale obtained from the validation results, Formula 1 is used:

$$\text{Ideal Percentage} = \frac{\text{Achieved Score}}{\text{Ideal Maximum Score}} \times 100\% \quad (1)$$

After obtaining the validation results from each validator, the combined validation is then calculated by incorporating the analysis results into Formula 2:

$$V = \frac{\text{Expert 1} + \text{Expert 2} + \dots}{\sum \text{Expert}} \times 100\% \quad (2)$$

The validity level of the developed e-module for each feasibility aspect is determined based on the Guttman scale results, as specified by the criteria in Table 2.

Table 2. E-module validity categorization

Score (%)	Qualitative Category
80,01-100	Highly valid, usable without revision
60,01-80,00	Valid, usable with minor revision
40,01-60,00	Less valid, not recommended for use due to major revision requirements
20,01-40,00	Invalid, unusable
00,00-20,00	Highly invalid, unusable

(Akbar, 2017)

All data obtained from the product design description analysis, as well as suggestions and feedback from experts during the validation process, were analyzed using the Miles and Huberman model (Sugiyono, 2015).

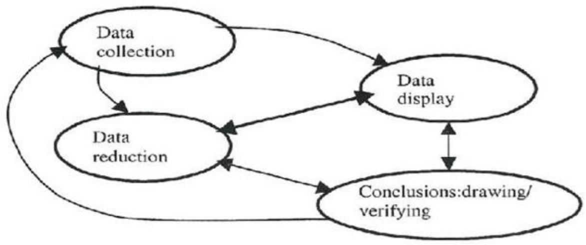


Figure 3. Miles dan Huberman's Model (Sugiyono, 2015)

The collected data were reduced by summarizing, selecting key points, identifying themes and patterns, and removing unnecessary information. The results of this reduction are presented in the form of descriptive narrative text. Following this, conclusions were drawn and verified regarding the characteristics of the developed intertextual-based e-module and the feasibility results provided by the experts. Suggestions and feedback from experts were utilized as a basis for revision to produce an intertextual-based e-module with the potential to enhance students' concept mastery of intermolecular forces and critical thinking skills.

Result and Discussion

The developed e-module was structured based on an intertextual approach. This approach was selected because it emphasizes the linkage between concepts, enabling students to construct a comprehensive understanding (Wiji, Widhiyanti, Delisma, & Mulyani, 2021). The e-module was developed using the ADDIE instructional method, which was limited to the first three stages: analyze, design, and development.

Analysis Stage

The first stage is needs analysis, which aims to produce a responsive and sustainable system (Tjahyanti & Sutama, 2024). Interviews were conducted with chemistry teachers to identify and analyze up-to-date potential, field issues, and actual needs. Subsequently, the research problem was defined, followed by a literature review related to the existing issues.

The second stage involves determining the chemistry topics to be discussed. This was done by analyzing difficulties and misconceptions that students still experience regarding chemical concepts through follow-up interviews and literature studies of related journals. At this stage, the researcher identified ‘Intermolecular Forces’ as the chemical concept to be addressed. This decision is supported by numerous studies (Gudyanga & Madambi, 2014; Vladusic et al., 2016; Suryaningsih & Bahriah, 2018; Sukib & Mutiah, 2020; Rahayu & Fitriza, 2021; Ma’rufah et al., 2022; Ulfah et al., 2024; Lahlali et al., 2023; Widarti et al., 2024) which consistently find difficulties and misconceptions in this topic. To prevent recurring errors, misconceptions identified from the literature review were analyzed to be specifically emphasized in the designed e-module.

The third stage is curriculum analysis, conducted on the currently applicable ‘Kurikulum Merdeka’. The concept of intermolecular forces is located in the Phase F (Capaian Pembelajaran, CP), as stipulated in the SK Kepala Badan Standar, Kurikulum, dan Asesmen Pendidikan KEMENDIKBUDRISTEK 032/H/KR/2024. Based on the Learning Outcomes, the content must include dipole-dipole forces, induced dipole-dipole forces, London (dispersion) forces, ion-dipole forces, induced ion-dipole forces, and hydrogen bonding, all of which must be connected to the physical properties of substances. These ‘Capaian Pembelajaran’ were then translated into ‘Tujuan Pembelajaran’ (TP), followed by the formulation of the ‘Alur Tujuan Pembelajaran’ (ATP) as a sequence to achieve the goals. To measure learning attainment, ‘kata kerja operasional’ (KKO) based on the revised Bloom's Taxonomy by Anderson and Krathwohl (2001) were used to formulate concept mastery indicators.

The fourth stage is concept analysis. A literature study on intermolecular forces was conducted using General Chemistry textbooks, such as Chang, R. (2010), Brown, T. D. (2018), Whitten et al. (2014), Silberberg, M. S. (2007), and Petrucci, R. H. (2017). These concepts were then analyzed based on Johnstone's three levels of chemical representation: macroscopic, submicroscopic, and symbolic.

The fifth stage is the analysis of existing chemistry e-modules. Existing e-modules were analyzed as a reference for developing a superior learning resource. The analysis revealed that existing e-modules have not optimally linked the three levels of representation, often only presenting one level (e.g., only macroscopic, submicroscopic, or symbolic). Furthermore, the e-modules existing most only contain text and images. This contradicts the research by Denisa & Astimar (2024) and Hafifah, Yerimadesi, Alizar, & Kurniawati (2025), which emphasizes that students are more motivated and understand lessons more easily through media that combine text, images, animation, video, and interactive simulations to suit various learning styles.

Design Stage

This stage involved designing the initial prototype of the intertextual-based e-module. The first step was creating the e-module outline, which contains the general initial design. At this stage, macroscopic phenomena were selected as discourse topics based on the analysis of the three levels of representation in General Chemistry textbooks. The next step was creating the initial product design. The previously analyzed chemical multiple representations were integrated into the design. Subsequently, formative and summative questions were developed based on Anderson & Krathwohl’s (2001) cognitive levels and Facione’s (2015) critical thinking indicators. The third step was the preparation of feasibility and descriptive analysis instruments. The instruments utilized a Guttman scale for expert validation. These instruments were adapted from the requirements for good e-modules published by Depdiknas (2008) and Kemendikbud (2017), with modifications to include Johnstone’s (1993) content aspects, constructivist pedagogical aspects, and Mayer’s

(2003) media aspects, developed through consultation with supervisors.

Development Stage

In this stage, supporting media were selected and the product was developed to produce the final intertextual-based e-module format for intermolecular forces. The e-module links the three levels of representation, integrates the constructivist 5E model (*engagement, exploration, explanation, elaboration, and evaluation*), and incorporates Facione's (2015) critical thinking indicators. The final format was developed using Canva and uploaded to the Heyzine website. According to Rizal (2023), Heyzine is an ideal platform for e-module dissemination due to its interactivity and user-friendly navigation. Additionally, Heyzine requires no installation, is web-based, and is compatible with various electronic devices (PC, laptop, smartphone), facilitating easy access for students.

The initial prototype was then characterized through descriptive analysis. Based on this, the e-module aligns with the characteristics set by Depdiknas (2008) and Kemendikbud (2017), as follows:

1) *Self-instructional*: The e-module supports independent learning with clear instructions and objectives. It uses simple and communicative language which, according to Aliyyah, Pangesthi, Dewi, & Handajani. (2025) and Sagala & Naibaho (2023), helps students grasp complex concepts. It also includes summaries (Sholeh, Hufad, & Fathurrohman, 2023) and exercises based on Anderson & Krathwohl (2001) and Facione (2015) to evaluate conceptual understanding.
2) *Self-contained*: All concepts of intermolecular forces are presented in a complete and thorough form, divided into three learning activities.
3) *Stand-alone*: The product does not rely on other teaching materials; all resources, images, videos, and feedback are provided within the module.
4) *Adaptive*: The e-module was designed to follow scientific and technological advancements, accessible anytime and anywhere via Heyzine.
5) *User friendly*: The e-module is easy to use by following the usage instructions and navigation guides included within it.
6) *Consistency*: this is reflected in the consistent use of fonts, spacing, and overall display within the developed e-module.
7) *Multimedia integrated*: the developed e-module utilizes features of electronic media, incorporating text, images, and videos, which are supported by audio narration to assist student learning.
8) *Intertextual-based e-module and adherence to learning principles*: The e-module integrates multiple chemical representations (macroscopic, submicroscopic, and symbolic) as a cohesive whole. This approach aligns with Gilbert & Treagust (2009), who state that an intertextual-based approach must link multiple representations in chemistry: macroscopic, submicroscopic, and symbolic. Furthermore, the developed e-module incorporates fundamental learning principles. It is structured based on a constructivist approach through the 5E instructional model (*engagement, exploration, explanation, elaboration, and evaluation*), which is tailored to the indicators of conceptual mastery and critical thinking skills through conceptual descriptions and both formative and summative assessments. According to research by Bybee, Taylor, Gardner, Scotter, Carlson, Westbrook, & Landes (2006), Astuti & Raida (2014), Hamise, Anom, & Tuerah (2019), and Djadir, Upu, Hasmullah, Rezky (2021), a student-centered learning process that adheres to constructivist principles encourages students to participate more actively. Moreover, several studies demonstrate that chemistry learning utilizing a constructivist approach can enhance motivation (Wardhani & Armini, 2022), conceptual mastery (Naf'atuzzahrah, Taufik, Gunawan, Sahidu, 2022; Djadir et al., 2021; Nursafitri, Santoso, Sumari, 2021), and critical thinking skills (Wardhani & Armini, 2022; Widana & Widyastiti, 2023), ultimately leading to improved student learning outcomes (Djadir et al., 2021).

The e-module product was subsequently validated by experts. The feasibility of the e-module was evaluated by two media experts, one linguistics expert, four instructional experts, and five substance (content) experts. These experts assessed the feasibility of the developed e-module. The suggestions and feedback provided by the media experts regarding the product are presented in Table 3.

Table 3. Results of the analysis of the quality intertextual-based e-modul according to experts

Expert Validator	Score (%)
Media	96.43
Languange	96.16
Instructional or Pedagogical	97.62
Content or Chemistry	92.00

Overall, the assessment results of intertextual-based e-module is 95,55%. Based on the validation results by media experts, languange experts, pedagogy experts, and content experts above, the average validator assessment shows highly valid, usable without revision. This shows that the quality of intertextual-based e-module is suitable for use by students.

Although the e-module can usable without revision, however, there are several comments and suggestions from the validator to be revised, thus the product of intertextual-based e-module becomes a better product. The suggestions and feedback from the experts regarding the developed e-module product are presented in Table 4.

Table 4. Suggestions and feedback from the experts

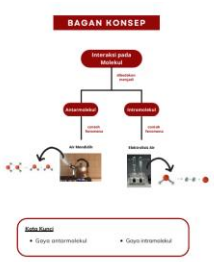
Expert Validator	Feedback
Media	Ensure the back cover matches the front cover's theme.
Linguistics	Pay attention to ambiguous sentences, spelling/writing, and punctuation.
Instructional or Pedagogical	1. Revision of '*Concept Chart*' to '*Learning Goal Achievement Flow*'. 2. Instructional video/learning video needs to be inserted into the learning activity section.
Content or Chemistry	Include animated videos illustrating the formation or mechanism of induced dipole-dipole, London forces, and ion-dipole interactions.

The improvements to the initial e-module product are detailed in Table 5.

Table 5. Outcomes of design revisions

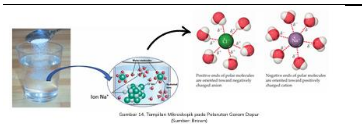
Before Revision	After Revision

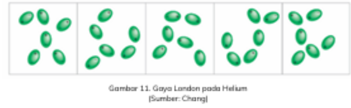
The design revision was conducted on the back cover of e-module to ensure consistency with the theme of the front cover. Additionally, english quotes within the e-module were translated into Indonesian to align with the language used throughout the module.

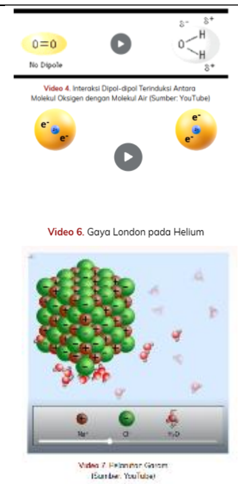


The title of 'Bagan Konsep' was revised to 'Alur Pencapaian Tujuan' to better reflect the instructional sequence. The macroscopic level is presented first, followed by submicroscopic and symbolic explanations. Additionally, the learning path was redesigned to illustrate the interconnections between concepts.

Before Revision	After Revision







The revision involved adding animated videos to illustrate the formation of induced dipole-dipole, London dispersion, and ion-dipole forces. These video illustrations aim to enhance students' understanding of the formation processes of these forces at the submicroscopic level.

The design revision was conducted on the cover, adjusting it to match the theme of the front cover. Furthermore, the illustrate of 'Alur Pencapaian Tujuan' was revised. In this revised flow, the macroscopic level is presented first, followed by explanations of the sub-microscopic and symbolic levels according to Intertextual-based principle, that are considered in helping students to construct and identify abstract chemical concepts within existing phenomena (Wu, 2003; Ryu et al., 2018). Additionally, animated videos were added to help students better understand the mechanisms of induced dipole-dipole, London forces, and ion-dipole interactions. Based on Nisrina, Wiji, & Widhiyanti (2025), Angelika, Junaidi, & Yasinta (2025), Alexandros, K. (2024), Hu, Gallagher, Wouters, Schaaf, & Kester (2022), the use of animated videos in science teaching effectively enhances students' comprehension, simplify complex scientific concepts, and can improve students to understanding in submicroscopic and symbolic representations.

Conclusion

Based on the findings and discussion from the development of the intertextual-based e-module on the concept of intermolecular forces, it can be concluded that the characteristics of the developed e-module align with the standards established by Kemendikbud (2017) & Depdiknas (2008). The feasibility test results from expert validations in content, instructional methods, languange, and media indicate that the e-module is both feasible and highly valid. Accordingly, the intertextual-based e-module on intermolecular forces has the potential to improve students' concept mastery and critical thinking skills**.** Further research is recommended to conduct field trials and empirical effectiveness testing to measure the actual impact of the e-module on students' learning outcomes.

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Author Contributions

Conceptualization, methodology, resources, and writing—review and editing, H.A., W.W., and T.W.; validation, W.W. and T.W.; formal analysis, investigation, data curation, writing—original, draft preparation, and visualization, H.A. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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