FEATURE ARTICLE

Fusion of Biology and Art: An Interdisciplinary STEM Education

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Abstract

Knowledge of scientific principles and practices is vital to creating informed citizens. At its core, science helps create citizens who question the why and how of things, while also increasing knowledge of the world and beyond. Humans by nature are curious and thrive when they are engaged in learning that relates to real-world situations relevant to their lives. Unfortunately, many scientific courses are based on rote memorization and regurgitation of knowledge taught in a lecture format. Active learning, on the other hand, in co-taught non-majors biology classes has been found to be an effective methodology that allows students to more easily understand presented concepts. This paper will detail activities and student data for an elective interdisciplinary non-majors biology course taught at the University of Mary Hardin-Baylor. Titled "The Visual Art of Biology," this class was a collaboration between the Biology and the Art departments. It was offered in Spring 2022 and had 12 students from various majors, including graphic design, biology–pre-physician assistant, studio art, art education, and business management. The class was structured so students would learn biological concepts and incorporate those ideas into artistic creations. Students learned about the impact of global warming, species invasions, habitat destruction, and biodiversity. In addition, they investigated various materials and ecological systems while considering the potential impact of their own actions when making art. Assessments involved quizzes, exams, reflective essays and research papers to gauge understanding of content and allow instructors real-time feedback. Comments were positive through course evaluations, written emails, and verbal feedback.

Key Words: *scientific knowledge; informed citizens; non-majors biology class; active learning; interdisciplinary course; artistic creations; biodiversity; student exploration.*

○ Introduction

Biology, a dynamic and continuously evolving field of study, intersects with an array of other disciplines, including chemistry, physics, mathematics, computer science, and engineering (National Academies of Sciences, Engineering, and Medicine, 2018). This inherent interdisciplinary nature of biology (the intersection of two of more disciplines) serves as fertile ground for students to amalgamate insights and expertise from diverse domains. Such collaboration leverages varied perspectives, methodologies, and research approaches, transcending the limitations of a single discipline. For students not immediately interested in majoring in biology, the benefit of increasing connections of learned subject matter to fields and areas they may be more interested in can be invaluable. The Vision and Change in Undergraduate Biology Education report emphasizes the need to cultivate six core competencies for undergraduate biology students, including the ability to "tap into the interdisciplinary nature of science" (Brewer & Smith, 2011). Consequently, there is a burgeoning movement toward interdisciplinary biology education, fostering the integration of knowledge and skills from multiple disciplines to address intricate biological challenges.

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Interdisciplinarity is far from a novel concept. Historically, art and biology have intersected, leading to numerous scientific breakthroughs. Santiago Ramón y Cajal, a neuroscientist, pathologist, and artist, pioneered the mapping of the human brain, contributing to subsequent discoveries regarding neuron structure and plasticity (Bentivoglio, 2023; Finger, 2005). Cajal was able to make these discoveries through meticulous scientific observations under a microscope that led to his hypothesis that the brain is composed of individual neurons rather than a continuous network, which was the prevailing belief at the time (McGowan, 2014). Cajal's artistic background allowed him to visualize and communicate complex scientific ideas effectively and his drawings served as not only artistic representations but also scientific tools that conveyed his discoveries to the broader scientific community. Leonardo da Vinci, renowned as the founder of functional anatomy, unveiled the fundamental laws of human body structure and organ topography through his art (Jones, 2012). Leonardo's detailed studies of human anatomy, based on dissections of human corpses, allowed him to depict the human body with unprecedented accuracy featuring

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muscles, organs, bones, and blood vessels (Jones, 2012). He applied scientific knowledge to his art, using principles of engineering, physiology, and optics to enhance his drawings and paintings. Today, the drawings created by both scientists remain integral to their respective fields. They demonstrated the power of visual communication in scientific discovery.

There are several innate benefits in the interdisciplinary fusion of science and art (Adkins, Rock, & Morris, 2017). It encourages students to tackle complex issues from fresh viewpoints, enriching their comprehension by merging insights from various fields. Specifically incorporating art into science yields its own merits, one being an enhancement of student comprehension (Nichols & Stephens, 2013). When a student is able to understand a concept from multiple angles, their comprehension of that subject is increased. In addition, adaptability, innovation, and connections between the disciplines are also fostered. This encourages students to explore innovative ideas and novel solutions beyond traditional boundaries.

Challenges are inherent, however, in implementing interdisciplinary courses. One such obstacle is the presence of departmental silos in many educational institutions, hindering effective collaboration among teachers from different disciplines. Additionally, rigid degree plans with fewer elective course options often impede students from enrolling in interdisciplinary courses. Notwithstanding these hurdles, there is a growing enthusiasm for interdisciplinary education in science and art. This arises from the mounting recognition of the value of integrating diverse modes of thinking to resolve intricate problems (Huang, 2010).

Scientific and artistic endeavors both demand meticulous attention to detail and keen observation (Green, Trundle, & Shaheen, 2018). The interdisciplinary course, "The Visual Art of Biology" aimed to intertwine the intricacies and aesthetics of Biology with Art. Offered in Spring 2022, 12 students from various majors learned biological concepts and integrated them into artistic projects. Focusing on practical applications, students were able to connect theory with practice, enhancing their skills in collaboration and communication. Students took multiple-choice exams and quizzes, and answered open-ended questions to reinforce learning and encourage critical thinking. Students also wrote research papers and reflective essays on papers or concepts learned in class. This paper details results from an assessment and reflective paper submissions. Ultimately, this class benefited students by expanding their viewpoints and deepening their appreciation of the world around them. Understanding science is crucial for developing well-informed individuals. Through the creation of the interdisciplinary biology/art class and the innovative active-learning activities, we slowly created not only change-seekers but change-makers.

○ Methods

In this course, a unique instructional approach was adopted by teaching non-traditional biology lessons in a discussion format and incorporating art-based activities to reinforce the biology concepts to enhance the learning experience. The instructors for the course were subject-matter experts in their field. The art faculty member taught students artistic and compositional design, environmental art, and use of colors and lines in making artwork. The biology faculty member taught information relating to environmental biology, specifically teaching on areas relating to environmental science, ecology, and global change. The semester-long course was administered two days a week for 80 minutes per class.

In the class, students engaged in a variety of art-based activities that enriched their learning experience. They explored cyanotyping, a photographic printing process that uses sunlight to create stunning blueprints, allowing them to understand the interplay between light and chemistry. Additionally, students learned the traditional method of making charcoal, gaining insights into the transformation of organic material and its historical significance in art. They also experimented with making ink from berries, discovering the natural pigments and the process of extracting and stabilizing colors from organic sources. Furthermore, the class delved into Audubon paintings, where students studied and recreated the intricate and detailed works of John James Audubon, enhancing their appreciation for biodiversity and the meticulous observation of wildlife. These activities not only fostered creativity but also deepened students' understanding of ecological and environmental concepts through hands-on interdisciplinary learning.

○ Course Objectives

- Understand the basics of environmental science and human's impact on the earth.
- Learn to accurately record data and effectively communicate different biological concepts.
- Develop questions and practice communicating with one's peers by engaging in thought-provoking and respectful discussions.
- Explore natural art materials and processes to deepen one's knowledge and connection to the environment.
- Gain insights into the history of artists who draw inspiration from the environment, focusing on movements such as Land Art, Environmental Art, and Ecological Art.
- Research and experiment with art that promotes environmental awareness.

○ Results

There were 12 students enrolled in the non-majors biology course during the Spring 2022 semester. The size of the course was limited due to the size of the art studio. The students had majors ranging from studio art (five students), biology–pre-physician assistants (two students), graphic design (two students), art-education EC-12 certification (two students), and business management (one student). Students were able to get either biology or art credit for the course depending on the course code they signed up for. If a student was enrolled in BIOL 2391 they received three elective biology credit hours and ARTS 2391 was the course code for the elective art credits.

An innovative interdisciplinary approach implemented within this course was a squid dissection and art activity. During this innovation, students initially learned about squid and their responses to environmental variables such as temperature, oxygen, and wind and how these can be impacted by climate change. Students also learned about the implications of overfishing for not just squid, but other sea life as well. Finally, students learned the different anatomical structures of the squid. Dissection of squid in non-majors biology classes is ideal because the activity can be completed with scissors and minimal previous knowledge of dissection techniques.

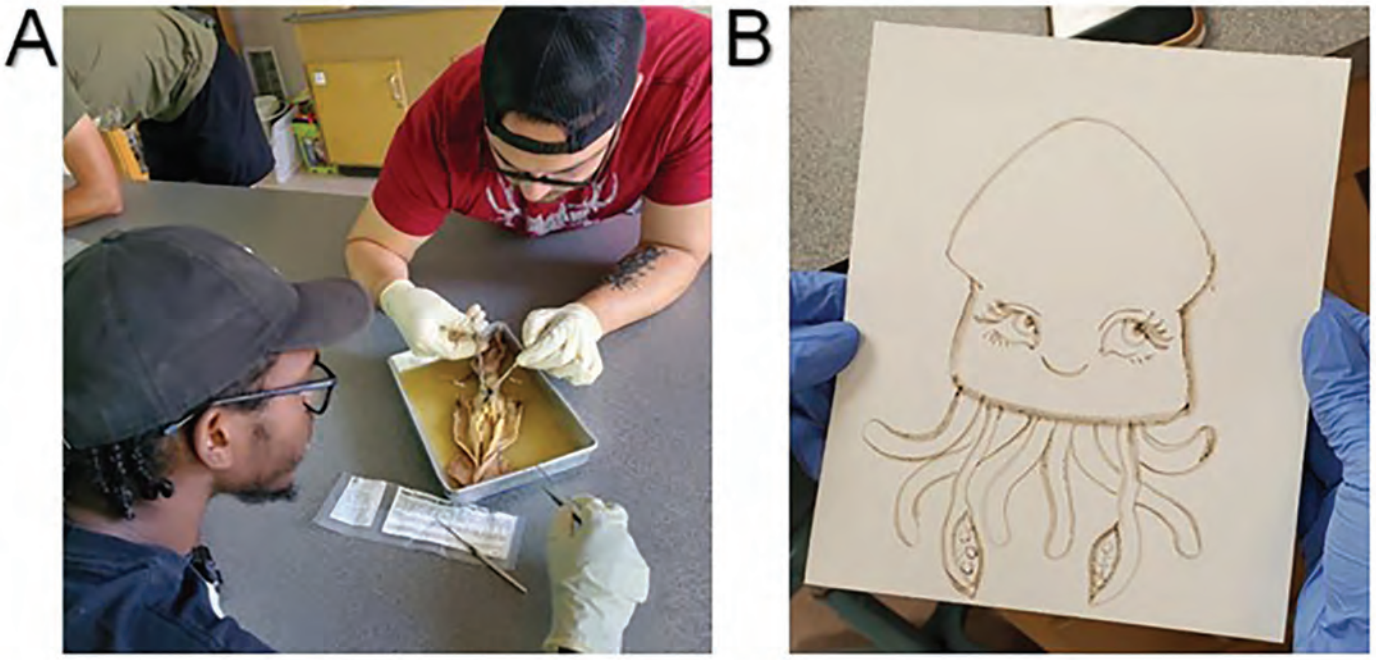

Figure 1. (A) Two students dissecting a squid. In the image, they are harvesting the ink sac to be used later to make ink. (B) Sample art created by a student using squid ink.

Students were able to actively dissect the squid on their own and remove the ink sac (Figure 1A). During the dissection, students were asked to identify various anatomical structures throughout. After removing the ink sacs, the ink granules were harvested. Due to the nature of the preservative, the ink was not in liquid but instead in powdered form. Students then learned how to create ink by adding different amounts of deionized water, resulting in varying intensities and colors of the ink. This allowed for a quick introduction of dilution ratios by the biology instructor for creating varying shades of color for the ink. Students then used the ink to create an artistic image of their own (Figure 1B).

Following the art activity, the details of the different types of ink and the historical implications of their use were discussed in depth by the art instructor. This collaboration and innovative activity engaged students in biology in a laboratory setting in a way that was non-threatening.

One measure of success was a quiz on this activity provided to students 2 weeks after the activity was conducted. Out of 12 students, 12 were able to recall proper dissection techniques and correct laboratory and safety behaviors. Ten of the students were able to properly recall squid anatomical structures and differences between males and females. Eleven students properly recalled impacts of climate change on squid survival. All twelve students were able to accurately describe, in depth, the details of the activity, what they were engaged in, and why learning this material was important (Table 1).

Student engagement in the dissection portion increased throughout the class period. Questions posed were related to squid anatomy, physiology, and human impact on squid survival. This section helped students build skills "in developing questions and communicating with one another," which was one objective for the course. A student's reflective paper written after completion of the lab stated, "As someone who hasn't gotten to do a dissection since freshman year of high school, I was overjoyed to be able to participate in the lab. Not only was there a dissection but we also got to use the ink we scraped from the squid. After grinding the ink particles and adding water to the solution, we had drawable ink. We all took turns drawing and experimenting with ink. It was a wonderful thing to see where science and art intersect."

Students thrive when they are engaged in course content that relates information and learning to real-world scenarios. This innovative activity intertwined the impact of climate change to animal health, the impact of overfishing to animal survival, and the resulting use of animal ink to make art.

Another interdisciplinary approach to teaching involved linking land ecology and indigenous art. The class section began with a discussion on the basics of land ecology, including topics such as ecosystems, biodiversity, and the impact of human activities on the environment and animals. Students also learned about the interactions of indigenous people with the land. Historically, indigenous knowledge systems have developed over millennia through direct interaction with the environment. Indigenous practices also often promote biodiversity by maintaining diverse habitats and species (Griffin, 2024). Students learned integrating indigenous knowledge into modern ecological practices is a benefit to maintaining diversity and explored how ongoing legal and political changes could hinder these integration efforts. An in-class discussion on potential strategies to manage these challenges if the student was in charge followed. For homework, students researched indigenous art and traditional art techniques.

Students created art pieces to reflect art carvings they learned about in their research (Figure 2A). Previously in the course, students created their own charcoal by burning dry hardwood in a ventilated metal coffee container over a fire pit. The ink for the indigenous art unit was made using charcoal and rocks or stones picked up around campus.

Students also created a mural where they drew different carvings and images that were learned in their research. Figure 2B shows two students painting images on the mural using ink they created from

Table 1. Sample quiz questions presented to students after completing the interactive squid activity.

Assessment	Correct Answer
What is the first step in preparing a squid for dissection? a. Removing the ink sac b. Pinning the squid to the dissection tray c. Rinsing the squid with water d. Making an incision along the mantle	c
Which of the following is not a recommended safety practice in the laboratory? a. Wearing safety goggles b. Wearing gloves when handling chemicals c. Tying back long hair d. Eating and drinking in the lab	d
What is the function of a squid's siphon? a. Digestion b. Locomotion c. Reproduction d. Respiration	b
Which of the following is a distinguishing feature of a male squid? a. Presence of nidamental glands b. Larger size c. Hectocotylus arm d. Ink sac	c
Rising ocean temperatures due to climate change can lead to a. Increased squid populations b. Altered migration patterns c. Enhanced ink production d. Reduced predation	b
Which of the following is a potential consequence of climate change on squid habitats? a. Expansion of suitable habitats b. Increased food availability c. Habitat loss and degradation d. Improved water quality	c

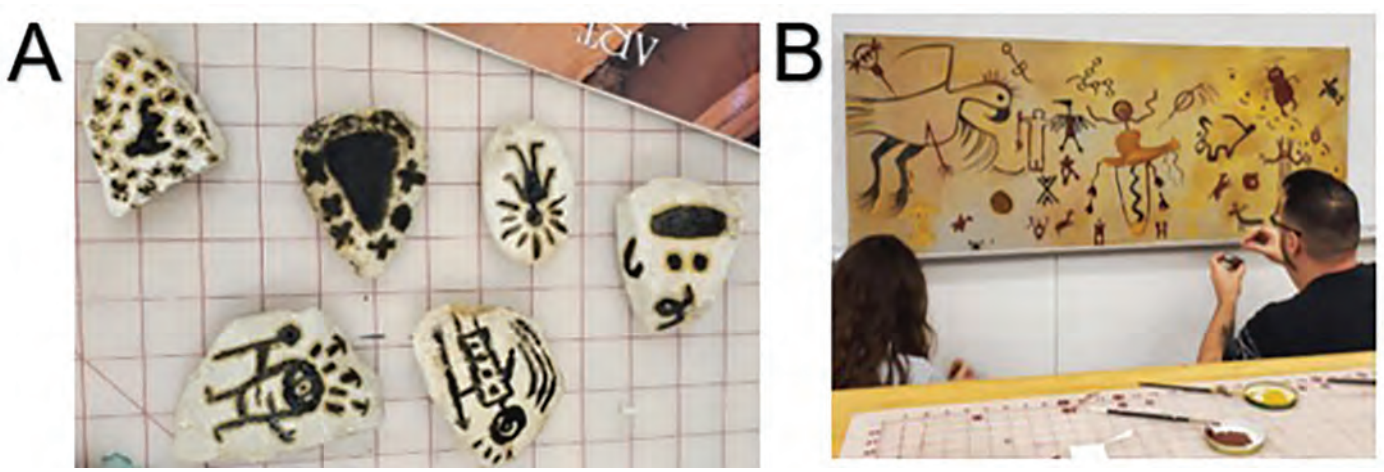

Figure 2. (A) Image of rocks painted with artwork using charcoal. Images show symbols mimicking aboriginal symbols of mountain, ants, man, and spear. (B) Two students creating an indigenous art mural using ink created in class. This activity was done after learning about land ecology and basic chemical reactions.

berries and natural plant materials or charcoal. The tools students used were meant to replicate the tools used by indigenous people.

This section of the course not only enhanced students' understanding of ecological principles but also fostered a respect for indigenous cultures and their deep connection to the land. The objective of this section was for students to understand the principles of land ecology, the cultural significance of indigenous art, and to create an art piece that reflects these ecological concepts through indigenous art techniques. Specifically, the course objective "explore natural art materials and processes to deepen one's knowledge and connection to the environment" was supported by this activity.

Students continued doing investigative research after completing the indigenous art unit. An excerpt from a student research paper details some concepts learned.

> We as humans (either advertently or inadvertently) have been negatively affecting the environment, and art directs our attention towards our impact on earth's ecosystems. Ever since we shifted from a nomadic lifestyle to a community based lifestyle we have destroyed our environment with deforestation, overfishing, pollution, etc. in the name of progress in pursuit of a higher quality of living. Various artworks turn our attention towards our environmental impact. Stefan Dam's glass blown jellyfish is an excellent example of this phenomenon. Dam's glass jellyfish are presented in a glass casing with bubbles to make the glass jellyfish seem like they are swimming. This depiction of glass jellyfish is eerie in a sense that possibly someday in the future this might be the only way we can see these creatures (Flannery, 2012). This effect allows us to ponder our own ecological footprint and its effect on the environment.

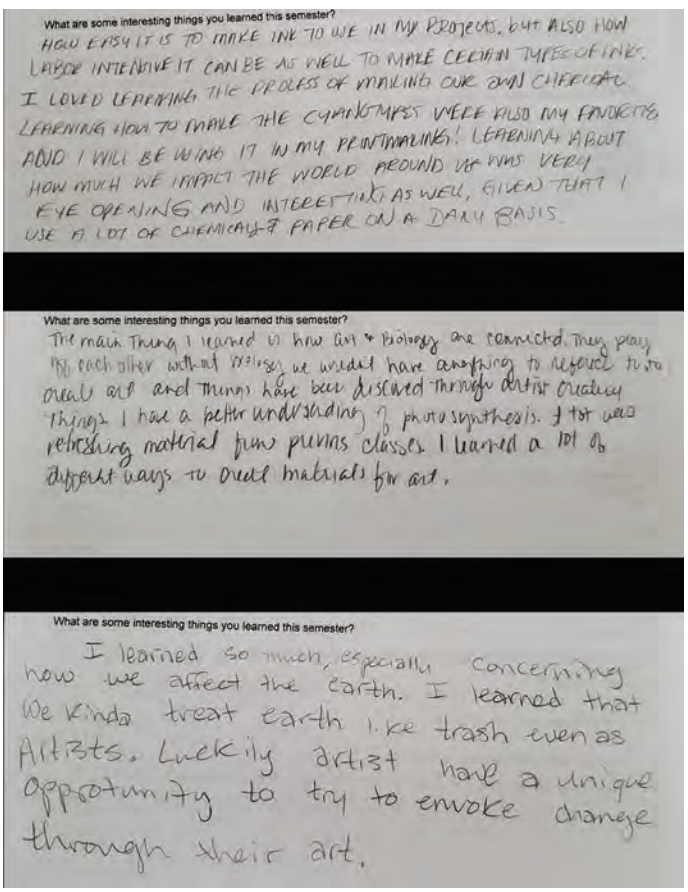

Figure 3. Sample student comments in response to the question, "What are some interesting things you learned this semester?"

Intersecting biological concepts with art in simple activities was impactful to the students as evidenced by some sample comments. When asked, "What are some interesting things you learned this semester?" one student commented "the main thing I learned is how art and biology are connected. They play off each other, without biology we wouldn't have anything to reference to create art and things." Another student wrote, "I learned so much especially concerning how we affect the Earth. I learned that we kinda treat Earth like trash even as artists. Luckily artists have a unique opportunity to try to [evoke] change through their art." Additionally, one student noted "how easy it is to make ink to use in my projects, but also how labor intensive it can be as well to make certain types of ink. I loved learning the process of making our own charcoal. Learning how to make the cyanotypes were also my favorite and I will be using it in my printmaking! Learning about how much we impact the world around us was very eye opening and interesting as well, given that I use a lot of chemicals and paper on a daily basis" (Figure 3).

Finally, "art and biology are closely interconnected with each other by inadvertently making us aware of the impact we have on the environment.…Art and biology are thought of being in two different worlds when in actuality they are two sides of the same coin."

○ Discussion

The implementation of an interdisciplinary non-majors biology course was a unique method for imparting biological knowledge to students outside the major. Results from assessments and student feedback highlighted the course's success in achieving its educational objectives.

Encouragingly, student feedback reflected positively on classroom activities such as the squid dissection, with several expressing surprise at the simplicity of ink production, as evidenced by comments such as, "I was surprised by how easy it is to make ink." Other comments suggest the squid dissection and associated interdisciplinary approach caused students to analyze and look at their environment in a different way.

By exposing students to diverse perspectives, the course facilitated a multifaceted understanding of biology. For example, the indigenous art unit played a crucial role in deepening students' understanding of land ecology and environmental stewardship. By immersing students in indigenous perspectives, the course fostered a holistic appreciation of biodiversity and the importance of maintaining the Earth. For example, the creation of traditional art pieces using natural materials highlighted the interconnectedness of cultural practices and ecological knowledge. This activity encompassed elements of land management, conservation, and sustainable practices, allowing students to see the intricate balance required to preserve ecosystems.

The squid dissection activity integrated aspects of anatomy, physiology, environmental science, and ecology, helping students understand how different factors contribute to the squid's survival within its habitat. Furthermore, the interdisciplinary approach honed student's critical thinking skills. Encouraging them to consider biology through multiple lenses enhances analytical thinking, a vital skill with broad applications across various fields and endeavors.

The course's ability to bridge the gap between academic learning and real-world relevance was evident. The innovative activities discussed integrated topics such as climate change's impact on animal health, overfishing's consequences for animal survival, and the utilization of animal ink in art creation. Student comments highlighted the profound impact of this holistic approach, with one student remarking, "The concept of art and biology is not one that I can say I've really ever thought of before. Even when signing up for this class and talking with my advisor, I was confused as to what this class would be about and what exactly art and biology ultimately had to do with each other. It has been interesting to explore this concept, and it has sort of made me feel dumb, for lack of better words, for not being able to realize that biology and art are interconnected and related in so many ways."

Building on the success of the interdisciplinary course, several avenues for improvement and expansion in traditional biology courses become apparent. These include incorporating activities that expose students to biology from diverse angles, fostering discussions and debates around course material, and encouraging the application of biological knowledge to real-world problem-solving scenarios.

In summary, the interdisciplinary biology/art course tailored for non-major students emerged as an effective and engaging means of delivering biological education. It not only improved student learning but also demonstrated adaptability, with potential applications across various biology topics, including land ecology and anatomical structures. Consequently, I recommend that instructors teaching non-majors biology courses explore the merits of adopting an interdisciplinary approach to enhance their students' learning experiences. By integrating biology and art in an interdisciplinary class and employing creative, hands-on learning methods, one can gradually nurture students who not just seek change but drive it.

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