



Frankenfish: A Fish Adaptation Puzzle

ACTIVITIES AND
PROGRAM MODEL

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ABSTRACT

Frankenfish is a life science activity for grades 4–6 during which students are challenged to create a fish with adaptations to help it survive in a given habitat. The activity combines constructive and interactive learning techniques to promote better understanding of marine science concepts. Students are constructive as they create fish outputs that go beyond the content ideas that they are presented, and these outputs often require elaboration by the student. This activity can be completed by students in pairs to create an interactive environment that encourages joint dialogue between peers and in which each student can make substantial contributions to the construction of their fish. *Frankenfish* provides an opportunity for students to learn about external fish anatomy without using live or specimen fish; it instead utilizes laminated drawings of fish anatomical features. Student learning objectives of this activity include the ability to give examples of habitats, particularly marine habitats, understanding the concept of adaptations and explaining what adaptations fish need to survive in their different habitats, identifying external fish anatomical parts, and the ability to connect extreme habitats and the adaptations that could benefit fish living in them. *Frankenfish* aligns with Next Generation Science Standards: MS-LS4-2 and 4-LS1-1 and with Ocean Literacy Essential Principles: Principle 5d.

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Constructive and interactive learning styles in both formal and non-formal learning settings have been shown to increase students' understanding of presented material (Menekşe 2012). Chi (2009) defines a *constructive* activity as one in which the output goes beyond the information provided by the lesson and that often requires further explanation by the student. *Interactive* activities are defined as those in which students are talking to another person, such as a peer (Chi 2009). Interactive activities that involve a learner interacting with a peer can further be defined as *joint dialogues* which occur when both peers contribute to the activity discussion (Chi 2009).

Particularly in non-formal learning environments, constructive and interactive activities are a valued way to engage students in unfamiliar topics. Science lessons that occur at non-formal education centers are positively correlated to students' ability to connect formal science lessons to everyday life, attitudes toward science concepts and learning, intentions for further study, and career aspirations (Tamir 1991). Non-formal education centers serve as a bridge between the classroom and everyday life. Kisiel (2005) found that lessons at non-formal centers reinforce classroom curriculum and provide additional perspective to students, as well as enhance interest and motivation to learn. Lessons at these types of centers not only enrich learning for students, but they also provide education opportunities for students with varying abilities to learn science (Hofstein & Rosenfeld 1996). The University of Georgia Marine Education Center and Aquarium (MECA) with its focus on of "hands-on, feet-in learning" is a prime example of a non-formal education center that prioritizes this type of learning.

Educators at MECA teach classes on a wide range of marine science topics including marine invertebrates, plankton, marine debris, and, as an aquarium, there is certainly an emphasis on fish studies. MECA offers aquarium tours with behind-the-scenes access, an introduction to fish, fish taxonomy, fish dissection, and even Gyotaku, the art of Japanese fish printing. We have created an additional activity to add to our fish studies suite called *Frankenfish*, an activity used to teach students about fish adaptations to their habitats.

Fundamental to ichthyology is understanding anatomical features of fish, as these features are the basis of understanding species classification, locomotion and the ecology of a fish (Moyle & Cech 1981). Through examination of a fish's body shape, eyes, fins, mouth, teeth, patterns and miscellaneous structures, one can make inferences about a fish's life history and habitat.

Fish body shape is often a quick and apparent way to begin to classify fish. The shape of a fish's body often relates to its style of predation (e.g., lie-in-wait or searching out prey) or where it lives (e.g., on the bottom or in reefs) (Moyle & Cech 1981). In addition to identifying a fish's body shape, exploring its fins, specifically caudal fins, can be a way to continue to learn clues about the fish. The shape of a fish's caudal (tail) fin can indicate swimming speed, the position of the anal fin can indicate directional movement abilities, and the style of all fins, particularly pectoral and dorsal, can indicate predator deterrence (Moyle & Cech 1981). To understand a fish's main prey, examine the mouth. Its mouth can provide information about a fish's habits by its position (e.g., downward- or upward-pointing), shape, and size. An examination of a fish's teeth can indicate how a fish gets its food (e.g., stabbing or scraping) (Moyle & Cech 1981). A fish's eyes can tell where it lives (e.g., on the bottom), how it feeds (e.g., by finding bioluminescent prey in the deep sea) or when it hunts (e.g., at night) (Moyle & Cech 1981).

During the *Frankenfish* activity, students engage in instructional dialogue with an educator about aquatic habitats, adaptations fish need to survive in their habitats and the basic external anatomy of fish. Students then have a chance to explore laminated external anatomical fish pieces at their stations. After exploration, students are challenged to work in pairs to create a fish that can survive in a habitat scenario described by the educator. Students are then offered the opportunity to share their creation with the class. After a few rounds, students are encouraged to create their own habitat scenario and imagine what adaptations a fish would need to survive.

Time honored fish adaptation activities including Fashion a Fish (Association of Fish & Wildlife Agencies) and Design a Fish (Student Activity: Design a Fish, 2009) may be used as resources for *Frankenfish* activity pieces. However, *Frankenfish* is, to our knowledge, the only such activity that allows students to create a fish from parts based on given scenarios before giving them the opportunity to imagine habitat scenarios of their own.

This activity provides educators with a way to teach about fish without using fish specimens, which can be a barrier for some schools and situations in the form of time availability, supply of materials, financial resources, student allergies, student comfort with handling animals and the availability of proper teaching spaces. *Frankenfish* also provides students with the opportunity for a guided construction of a fish in a puzzle format, allowing them to play the role of Dr. Frankenstein to make a creature using the parts most needed to help it survive. Students are directed to “make a Frankenfish” which means to create a fish, particularly an unusual one, by combining the provided fish parts.

Frankenfish is recommended to be implemented in student pairs to encourage interactive joint dialogue (Chi 2009). Pair work, or cooperative learning, for middle school students can help to harness the high energy often present at this age and encourage pro-social time in the classroom (Slavin 1996). Additionally, cooperative learning has been shown to significantly reduce perceived stress for students from underserved communities, create greater equity in education, improve peer relations, reduce emotional problems for all students, and promote academic engagement (Van Ryzin and Roseth 2018; Van Ryzin, Roseth & McClure 2020; Van Ryzin and Roseth 2021). Mueller and Flemming (2001) found that students engaging in cooperative learning do require unstructured time during the activity to set team goals and create an organizational structure, so providing time for pairs to explore their fish pieces should not be skipped.

OBJECTIVES

- Students can give examples of habitats, particularly marine habitats.
- Students understand the concept of adaptations and can explain what adaptations fish need to survive in their different habitats.
- Students can identify external fish anatomical parts.
- Students are able to connect extreme habitats and the adaptations that could benefit fish living in them.

STANDARDS

This life science activity is designed for students in grades 4–6 following the standards below:

Next Generation Science Standards (NGSS Lead States, 2013)

MS-LS4-2 Natural Selection and Adaptations

Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.

4-LS1-1 From Molecule to Organisms: Structures and Processes

Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

Ocean Literacy Principle (National Marine Educators Association, 2024):

Principle 5: The ocean supports a great diversity of life and ecosystems.

5d. Ocean biology provides many unique examples of life cycles, adaptations, and important relationships among organisms (symbiosis, predator-prey dynamics, and energy transfer) that do not occur on land.

MATERIALS LIST FOR A CLASS OF 10 STUDENTS

- Five sets of laminated fish pieces with descriptions written on the back (Table 1).
- List of habitat scenarios (Table 2).
- Optional list of questions for students to consider during Frankenfish construction (Table 3).

<i>Mouth</i>	
Superior	Upward pointing; feeds near the surface on prey above it
Terminal	Located on the end of the head; feeds by chasing and capturing or picking at things
Sub-terminal	Located on the underside of head; feeds on bottom
Extremely large jaws	Feeds by surrounding prey; comes up from below to swallow fish whole, including bigger fish
Beak	Feeds by crushes small crustaceans or mollusks
Sucker/Protrusible	Feeds on small plants and animals
Tiny	Feeds on zooplankton
Barbels	Sensory organs, “whiskers” near mouth used to detect prey
<i>Body shape</i>	
Fusiform	Torpedo shaped; fast moving; cannot turn tightly or steer in close quarters
Compressiform	Vertical disk shaped; feeds above or below; can make tight turns in tight spaces; often lives in reefs; cannot swim fast in a straight line, so not safe away from reef
Depressiform	Horizontal disk shaped; bottom dweller
Truncate	Square shaped; slow, but able to maneuver and stay stable in fast moving water; must rely on camouflage and other adaptations to catch prey and avoid predators
Globiform	Round shaped; slow, but can increase body size to scare predators
Sagittiform	Rod shaped; long arrow-like body; useful for ambush hunting; can lunge quickly and move fast
Anguilliform	Ribbon shaped; tends to move slowly, but can move quickly through rocks and corals
<i>Pattern</i>	
Countershading	Light colored belly to hide from predators below, dark upper side to hide from predators above
Vertical bars	Hides in vegetation; stripes confuse predators in school because all fish blend together, but fish become conspicuous when alone in reef or open water
Horizontal stripes	Hides in vegetation
Mottled coloration	Hides in rocks and on ocean floor
Eyespot	Fools predators as to direction of fish’s head and allows for escape; would make a predator obvious
Bioluminescence	Used to attract prey or mates; mid-deep water
<i>Eyes</i>	
On top of head	Bottom-dwelling fish
Large	Better night vision
Frog-like	Two bulging eyes atop head; can move independently from one another for peripheral vision; retractable; nearly 360-degree vision
Stalked eyes	Atop long, cartilaginous stalks that allow for an increased range of vision
Telescoping	Tubular eyes; optimal binocular light collection, at the expense of lateral vision; can see prey’s weak bioluminescence from a distance; can see the outlined silhouettes of prey against the gloom above; help to better judge distance of prey; typical of deep-sea fish
<i>Tail shape (Caudal)</i>	
Truncate	Strong, slow swimmers
Rounded	Slow swimmers; short, accurate bursts
Forked	Fast, sustained swimmers; deeper fork equates to faster speed
Lunate	Strong, fast swimmers; continuously on the move
<i>Teeth</i>	
Pointed	Feeds by stabbing
Comb-like	Feeds by scraping materials off rocks
Beak-like	Fused; feeds by scraping materials off rocks
Incisor-like	Feeds by cutting
<i>Other fins</i>	
Pelvic	Located under pectoral fins for fine movements like pivoting and swimming backward; located in pelvic region for balance, but cannot swim backward or pivot
Pectoral	Large pectoral fins make the fish look deceptively large to predators
Dorsal	Sharp dorsal fin can be used as defense against predators
Adipose	Dorsal side, after dorsal fin before caudal fin. Used as sensory fin.
Anal	Located on the underside, in front of caudal fin; provides stabilization

Table 1 Suggestions of fish parts and descriptions for *Frankenfish* activity. Please see Appendix A for activity pieces. Credit for many of these goes to [Student Activity: Design A Fish, 2009](#).

Make a Frankenfish fish that swims in schools, eats zooplankton and insects, can fit in tight spaces, can swim backward, and has great vision.

Make a Frankenfish that lies flat on the ocean floor, eats smaller fish, and needs to camouflage itself on the bottom of the ocean.

Make a Frankenfish that feeds near the water surface and ambushes prey it sees above it. It is fast but cannot turn in tight spaces, so it needs to stay in the open ocean. This fish is nocturnal, and it has lots of predators living around it.

Make a Frankenfish that is a fast swimmer and can be found at the bottom of the water column where it is dark. This fish swims up to swallow bigger fish whole.

Make a Frankenfish that lives in logs, weeds, and under plants and likes to eat plants, small fish, and terrestrial insects. This fish avoids predators by hiding in vegetation and tries to make itself look larger to scare them away.

PROCEDURE

1. The educator starts an instructional dialogue to introduce fish adaptations and habitat and external fish anatomy.
2. Students spend time reviewing fish pieces in pairs and discussing them with the educator as a group.
3. Habitat scenarios
 - i. The educator slowly reads a habitat scenario and writes the key points on the board for students to reference. If there is no board or screen available, the educator can provide a handout with the written scenarios.
 - ii. Provide three to five minutes for students to construct their Frankenfish before allowing them time to share with the class (Figure 1, Figure 2, Figure 3). The educator may use optional thought-provoking questions to guide construction (Table 3).
 - iii. Once students have completed a few provided scenarios, allow them to create their own. Each group can imagine a scenario, or each group can provide one requirement for the scenario, and the class must create a fish with adaptations to meet each requirement.
4. Educators can conduct a wrap up conversation to include discussion of the diversity of organisms in the ocean, why fish can look remarkably different from each other, and why there are different adaptations that fish may use to survive the same habitat scenario.

What will your fish eat and how will it find food? Will it be a predator, prey or both?

Where in the ocean will your fish live, and what adaptations will best suit its habitat?

How fast does your fish swim, and does it need to swim long distances?

Will your fish need to swim backward?

How will your fish avoid predators? Will it have a defense, will it blend in, will it make itself look bigger?

What can you give your fish to give it an extra advantage in its habitat?



Table 2 Examples of habitat scenarios that can be used in Frankenfish activity.

Table 3 Examples of thought-provoking questions for students to consider while constructing their fish.

Figure 1 Students make a Frankenfish by combining parts to create a fish with adaptations suited for a certain habitat scenario. A student places a lunate tail on a depressiform fish body with pointed teeth.



Figure 2 Students make a Frankenshark by combining parts to create a fish with adaptations suited for a certain habitat scenario. A pair of students have created a fish with big eyes, incisor-like teeth, horizontal stripes, large pectoral fins, a truncate tail, and a pelvic fin on a compressiform body.

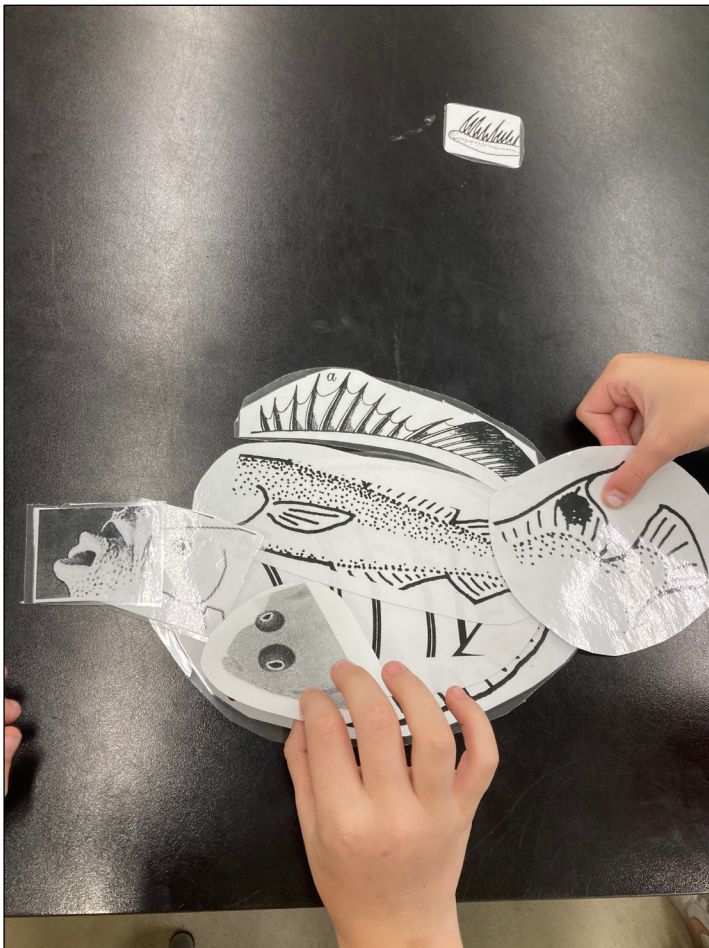


Figure 3 Students make a Frankenshark by combining parts to create a fish with adaptations suited for a certain habitat scenario. A pair of students have created a fish with a terminal and beak-like mouth, eyes on top of its head, countershading, an eyespot, vertical bars, and a sharp dorsal fin.

TIME REQUIREMENT

This activity is designed for 45 to 60 minute learning sessions. The shorter time frame would be more appropriate for classes who have already had an introduction to fish anatomy and require a shorter introduction. The shorter time frame is also appropriate for younger grades in the activity's age range.

MODIFICATIONS

Suggested activity pieces and scenarios have been provided, but educators can select fish anatomy pieces and habitat ideas that are best representative of their local environment and learning objectives.

Younger students may benefit from a shorter time frame and simpler scenarios.

This activity can be used for other organisms including both animals and plants.

EVALUATION

Twenty-seven students who had recently completed grades 4–6 took part in *Frankenfish*. After completing *Frankenfish* they were asked to create their own habitat scenario. They then traded habitat scenarios with a partner and created a Frankenfish based off the scenario created by their partner. These creations were used to evaluate the effectiveness of *Frankenfish* toward learning objectives. By creating their own habitat scenarios, students' understanding of fish habitats and adaptations could be evaluated. After trading scenarios with a partner, students recorded their choices for a Frankenfish body, caudal fin, mouth, teeth, eyes, pattern and other fins on a worksheet. This allowed for evaluation of students' ability to identify fish anatomy and understand fish adaptations to different habitats. Students turned in both the habitat scenarios and worksheets.

To evaluate this activity, each worksheet was compared to its habitat scenario, and each fish part selection was marked as correct, incorrect, or missing based on information provided in the scenario.

Twenty-seven students were evaluated by this method, though not all students indicated a choice for each fish feature, and not all habitat scenarios included a description that would require an adaptation to each feature. Out of 189 possible choices, students selected the correct feature for the habitat scenario 139 times and the incorrect feature 21 times (Table 4). There were 29 times that the habitat scenario did not require a specific feature (18 instances) or that a student skipped the selection of a feature (11 instances) (Table 4).

ANATOMICAL FEATURE	CORRECT	INCORRECT	NOT SELECTED
Body shape	23	2	2
Tail shape (Caudal)	21	2	4
Mouth	23	4	0
Teeth	21	4	2
Eyes	17	2	8
Other fins	16	6	5
Pattern	18	1	8
Overall	139	21	29

Table 4 Results of *Frankenfish* evaluation in numbers of correct and incorrect selections of fish anatomical features based on habitat scenarios created by other students. Also shown are numbers of students that did not select a particular feature and scenarios that showed no indication of needing one of these features.

DISCUSSION

Frankenfish is a hands-on activity that helps students to understand how fish adaptations vary based on habitat and how these adaptations help fish to grow, eat, reproduce and, ultimately, survive (NGSS 4-LS1-1). It also demonstrates how differences and similarities in fish anatomies are related to evolutionary changes to habitats and life histories (NGSS MS-LS4-2). This activity brings into discussion camouflage, predator-prey relationships and fish life histories of different species of fish in the ocean (Ocean Literacy Principle 5, 5d).

The constructive and interactive learning aspects of *Frankenfish* are valuable as they are more effective at improving student's subject knowledge than activities that do not utilize these

approaches (Chi 2009; Menekşe 2012). Chi (2009) provides pair-wise contracts of passive (viewing only), active (doing something while learning, often involving physical movement), constructive, and interactive activities based on a literature review of learning styles. Results of contrasts between constructive and passive styles almost always show increased learning during constructive activities. Chi (2009) found that the constructive style of asking students to self-explain a topic is more effective than not self-explaining (passive) or even paraphrasing a concept (active) (Chi et al. 1994; Klahr and Nigam 2004; Mitrovic 2005; Hausmann and VanLehn 2007; Kastens and Liben 2007). In a contrast of interactive and active activities and interactive and passive activities, Chi (2009) found that groups engaging in interactive activities outperformed (by providing correct answers or elaborating on a lecture) those engaging in passive activities and that interactive activities led to better results (filling in notes or demonstrating learning of material) than active activities (Ebert-May, Brewer & Allred 1997; Moreno, Mayer, Spires & Lester 2001; Mastropieri, Scruggs, Spencer & Fontana 2003; Doymus 2008).

Evaluations of students who completed the *Frankenfish* activity showed that students selected the correct anatomical feature for a given habitat scenario 73.5% of the time (Table 4). This indicates that this activity is effective in addressing the following learning goals:

- Students understand the concept of adaptations and can explain what adaptations fish need to survive in their different habitats.
- Students can identify external fish anatomical parts.
- Students are able to connect extreme habitats and the adaptations that could benefit fish living in them.

Out of 189 possible chances to include a needed fish anatomical adaptation in a habitat scenario, students only failed to include an adaptation 18 times. Each student was able to create a habitat scenario that fully or partially required particular fish adaptations, showing that *Frankenfish* is effective in addressing the final learning goal of:

- Students can give examples of habitats, particularly marine habitats.

Frankenfish allows students to be imaginative both in creating fish and habitat scenarios. Students tended to improve their partner work as the activity went on and became more willing to discuss their opinions and compromise. *Frankenfish* is a worthwhile addition to a marine science education experience when fish are not available to students. Additionally, students may benefit from interpreting fish anatomy in drawings instead of, or before, seeing them on a live fish. This can give students a firm understanding of what they are looking at and the differences they may have to look for in a live or specimen fish. Educators at MECA often teach *Frankenfish* before a fish taxonomy class using live specimens and before a visit to the in-house aquarium. This allows students to better grasp fish taxonomy and better identify anatomical features on live fish.

ADDITIONAL FILES

The additional files for this article can be found as follows:

- **Supplemental Document 1.** BodyShape. DOI: <https://doi.org/10.5334/cjme.120.s1>
- **Supplemental Document 2.** CaudalFins. DOI: <https://doi.org/10.5334/cjme.120.s2>
- **Supplemental Document 3.** Eyes. DOI: <https://doi.org/10.5334/cjme.120.s3>
- **Supplemental Document 4.** Mouth. DOI: <https://doi.org/10.5334/cjme.120.s4>
- **Supplemental Document 5.** OtherFins. DOI: <https://doi.org/10.5334/cjme.120.s5>
- **Supplemental Document 6.** Pattern. DOI: <https://doi.org/10.5334/cjme.120.s6>
- **Supplemental Document 7.** Teeth. DOI: <https://doi.org/10.5334/cjme.120.s7>

COMPETING INTERESTS

The author has no competing interests to declare.

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