Cracking the system: Explicitness of function and behavior in schematic textbook visualizations of DNA replication

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INTRODUCTION

Reform calls express that systems thinking is a vital skill in increasing scientific literacy[1]. Research has shown that students have a difficult time identifying and comprehending the function and behaviors of a system[2,3]. Using the Structure-Behavior-Function model[4] as the guideline for defining a system (Figure 1), this research will answer two research questions:

1. When a system is represented, to what degree does it make function and behaviors explicit?
2. How are functions and behaviors of systems being made explicit in textbook schematics of DNA replication?

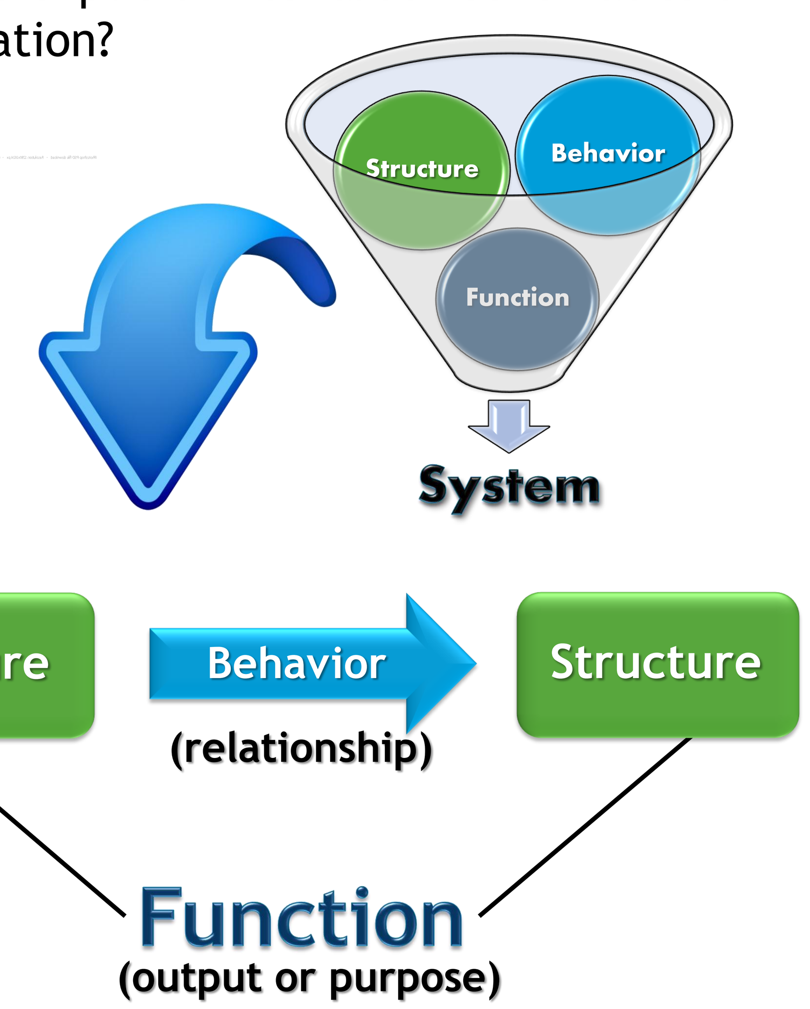
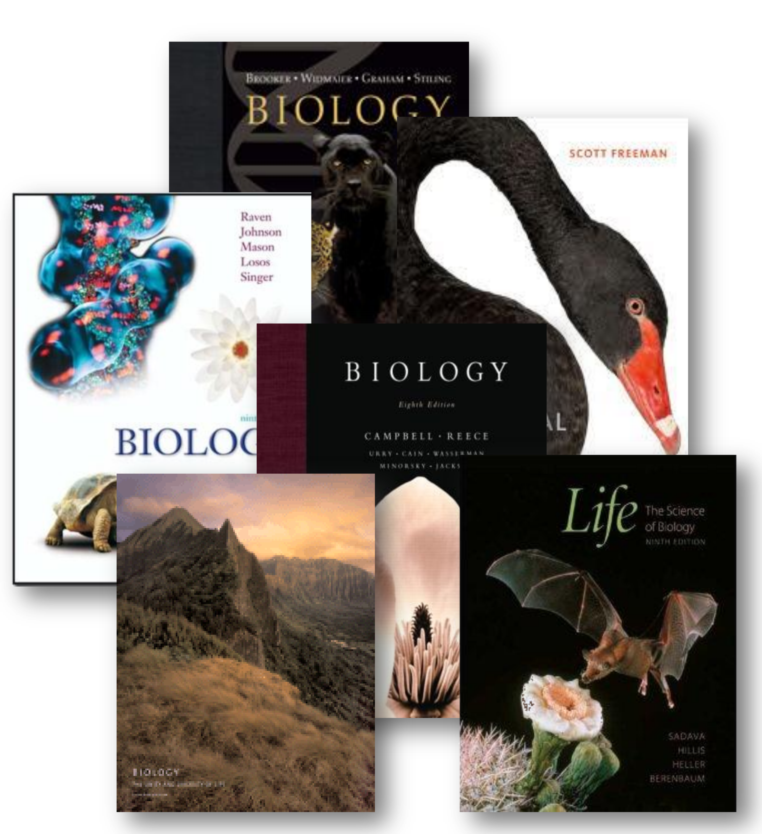


Figure 1
Components of a system. Structure, behavior, and function are three necessary parts of a system. This is a very rules-based model, but in textbooks, there appear to be no rules for creating models of systems.



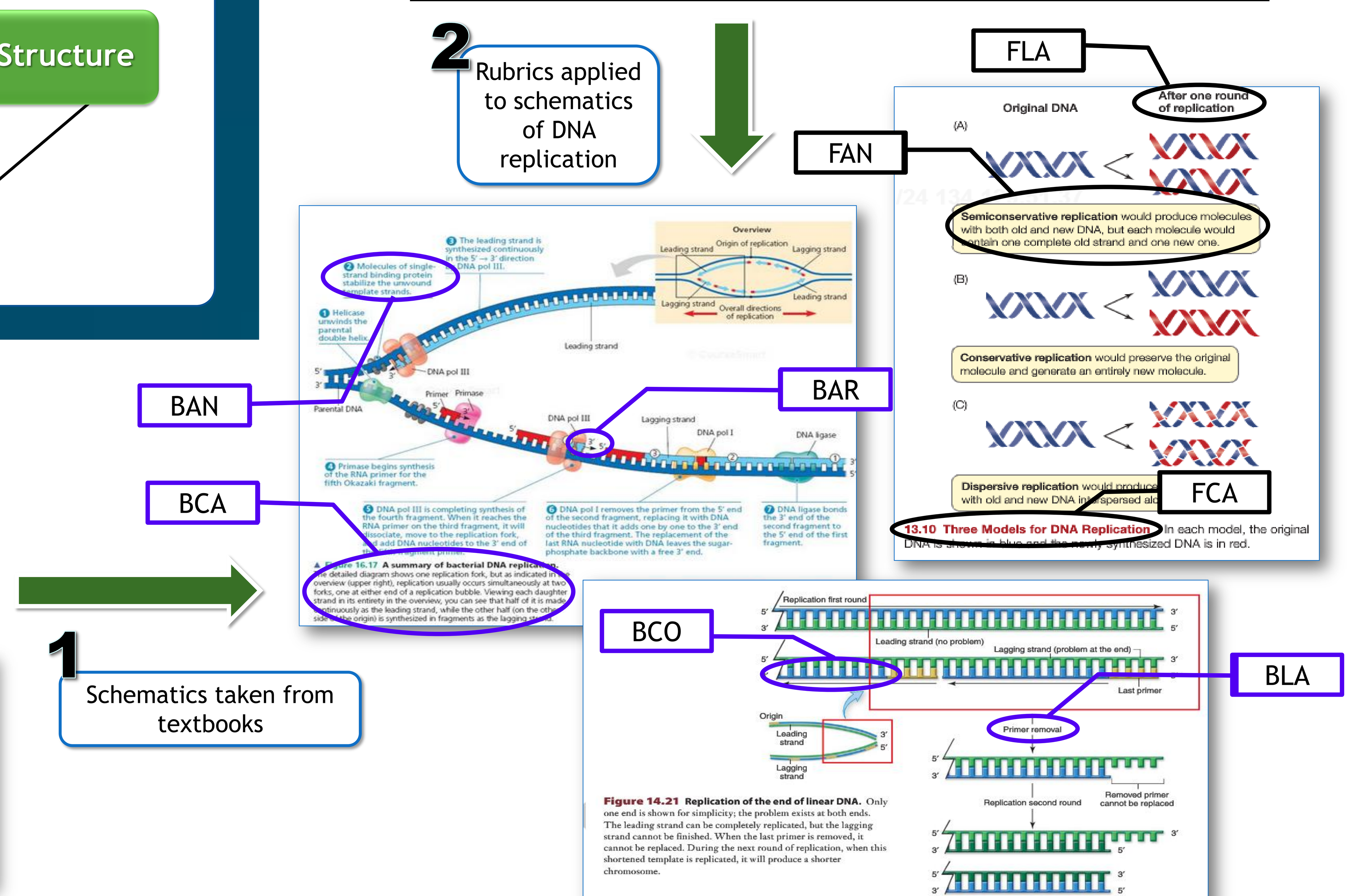
METHODS

Explicitness of Function in Systems Expressed in Figures

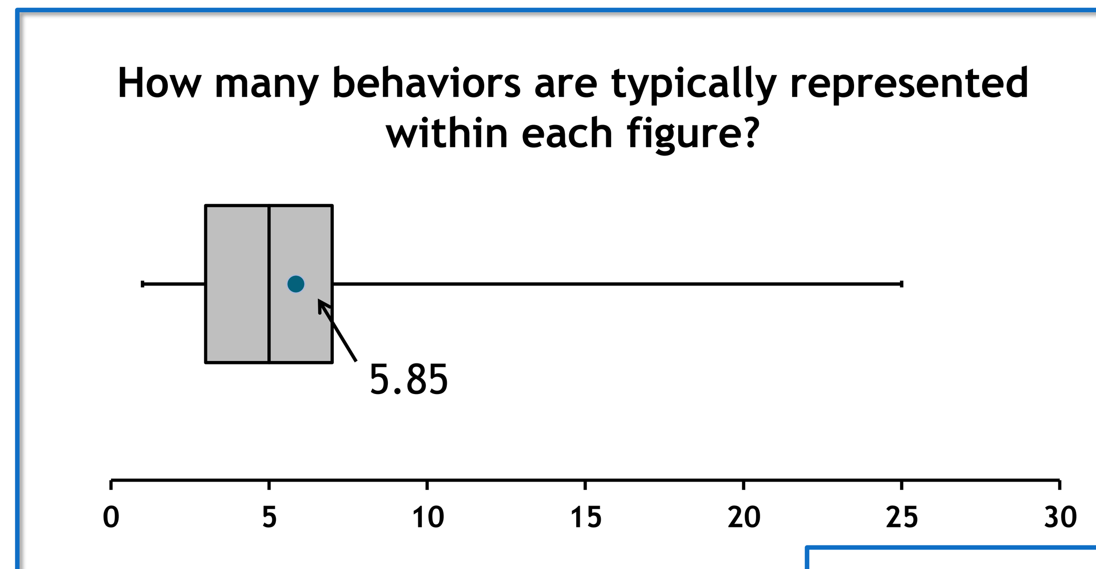
Classification	Criteria	Code
None	Function is present though it is not mentioned in the figure	FNO
Label	The function of the system is embedded in the figure itself using abbreviated text	FLA
Annotation	The function of the system is annotated within the figure (as in a pop out box or numbered box)	FAN
Caption	The function of the system is expressed within the caption of a figure	FCA

Explicitness of Behaviors in Systems Expressed in Figures

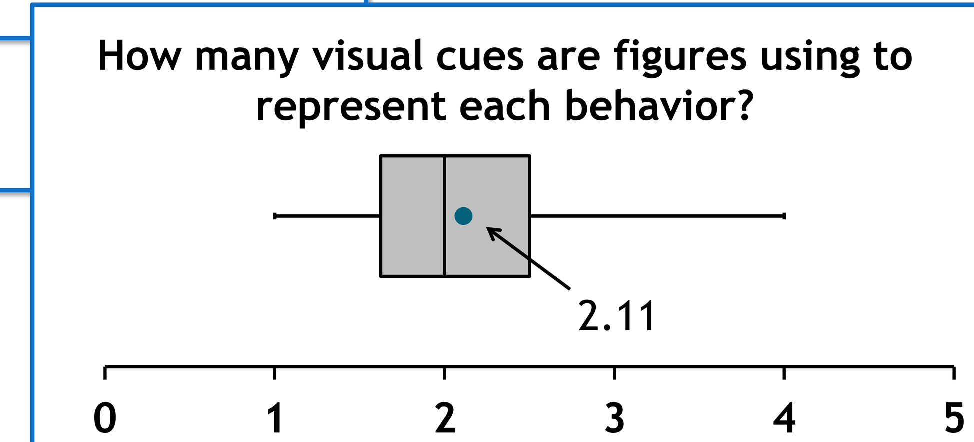
Classification	Criteria	Code
Color	The behaviors of the system are expressed by use of color	BCO
Arrow	The behaviors between two elements within the system are represented by use of an arrow	BAR
Label	The behaviors of the system are embedded in the figure itself using abbreviated text (e.g. above an arrow)	BLA
Annotation	The behaviors of the system are annotated within the figure (as in a pop out box or numbered box)	BAN
Caption	The behaviors of the system are expressed within the figure caption	BCA

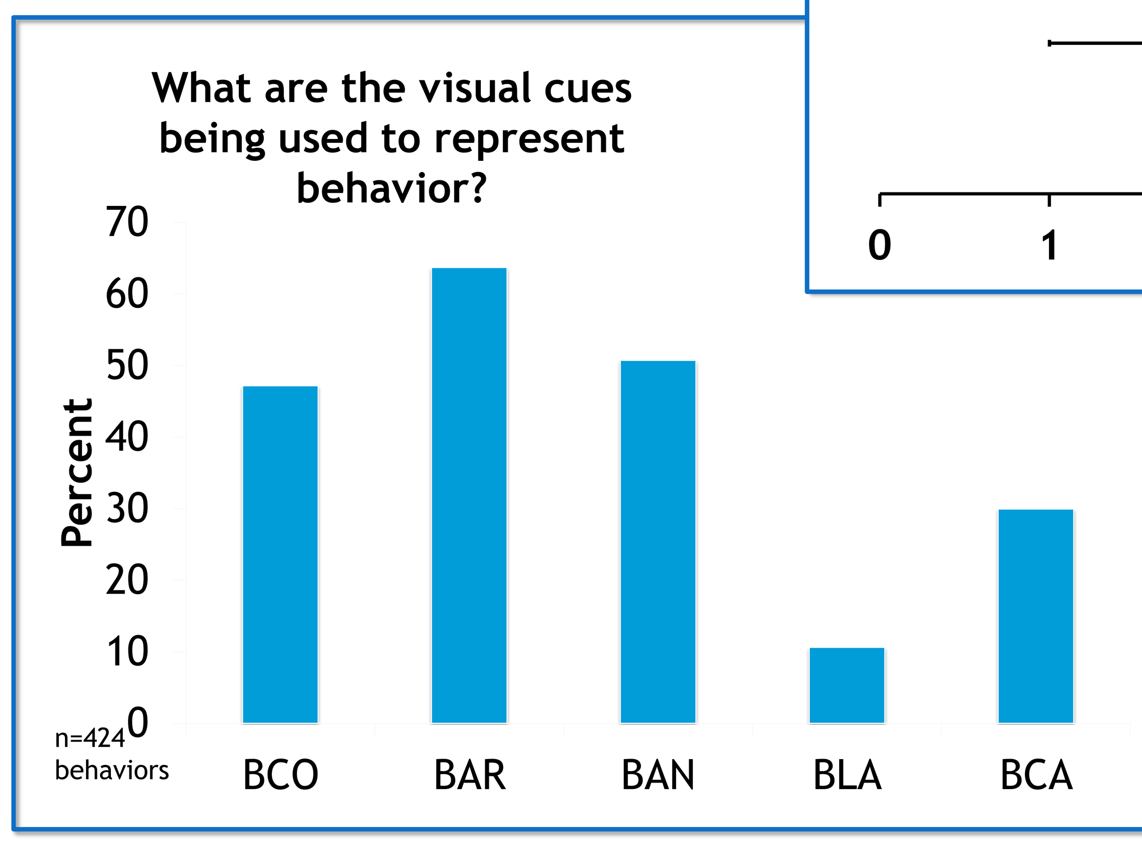


RESULTS

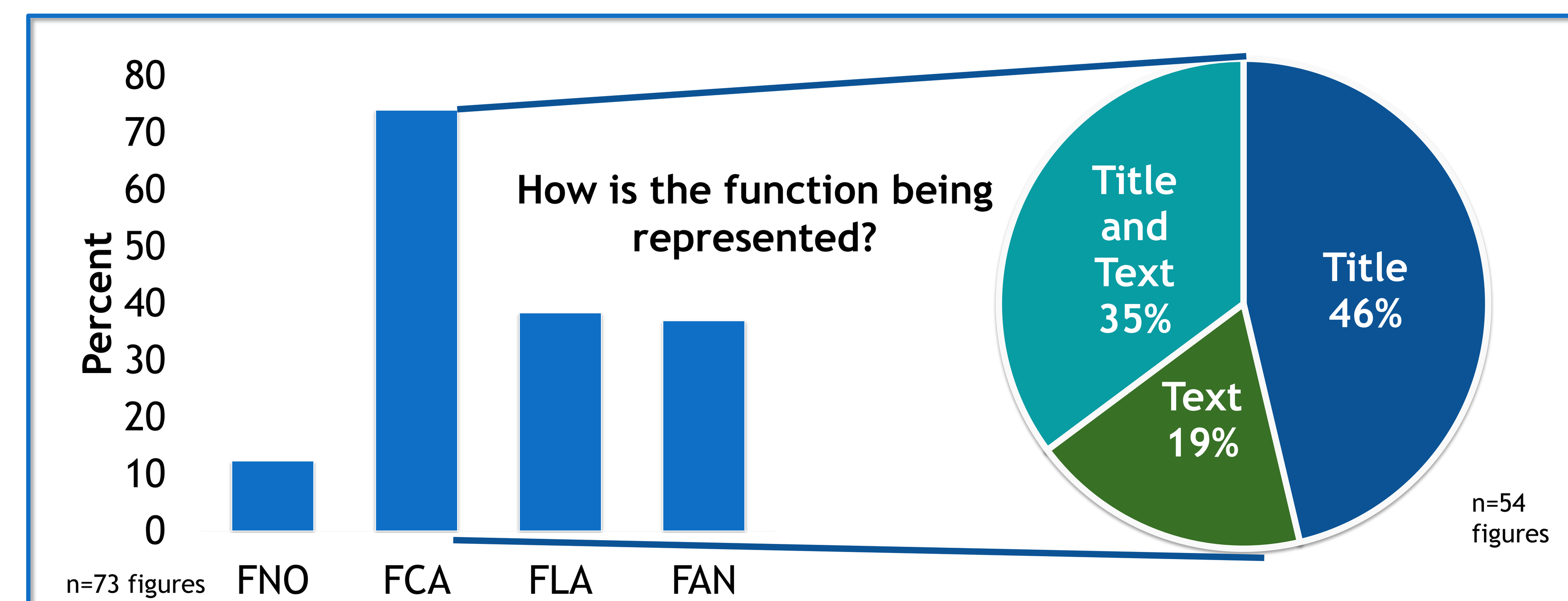


- On average, 6 behaviors are represented in figures
- Figures can have anywhere between 1 to 25 behaviors
- On average, 2.11 visual cues are given for each behavior





- 24% of behaviors are implicitly communicated (BCO, BAR, BCO + BAR)
- Captions are used as a visual cue to identify function 74% of the time
- 46% of captions only use the title to identify function



CONCLUSIONS

- There is wide variation in how systems and their components are represented
- Similarly, there is a large range of complexity among figures
- Students aren't always given all of the pieces necessary to unpack the system and its components
- Textbook figures are not designed to scaffold systems thinking, thereby possibly contributing to difficulties in student reasoning

FUTURE DIRECTIONS

- What do students believe a system is? How is this shaping their understanding of figures that model systems?
- To what extent are students able to identify as well as understand the behaviors and function of a system? By what methods are they reaching their conclusions as they interact with textbook figures?

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