Introductory Systems Thinking Instructions for SAFO-based Article Assignment

Terms and Descriptions

- SAFO: System Architecture-Function-Outcome
- For the 'Behavior' aspect, an interaction must be a causal relation, not a structural one. Interactions can involve matter, energy, or information. Behavioral interactions are time-dependent and dynamic.
- For the 'Function' aspect, a boundary system should share one or more parts with the target system (explicitly or implicitly). If it does not, then it is not a boundary system.
- Adherence pertains to how well the description of the system follows the assignment instructions as based on the SAFO construct.
- Correctness pertains to how well the description of the system matches with the content in the given source/s of truth or knowledge about the system.
- Adherence times Correctness equals Introductory Systems Thinking.

Scoring guidelines

- Adherence (Table S1): The adherence of a response should be based on the instructions provided to students as well as on inferences that can reasonably be made based on the totality of students' responses and on the content of those sources.
- Correctness (Table S2): The correctness of a response should be based on the sources of truth provided to students and that students reported as having used, as well as on inferences that can reasonably be made based on the totality of students' responses and on the content of those sources. Do not score responses that received '0' for adherence. Each aspect should be scored independently of all other aspects.

Table S1. Scoring instructions for Adherence.

SAFO aspect and element		2	1
Architecture	Structure	Five different parts AND majority are technological	Five different parts AND majority are not technological OR Four or six different parts AND majority are technological
	Behavior	Four different explicit interactions (cause-and-effect relationships) that together cover every part mentioned under 'Structure'	Four different explicit interactions that together do not cover every part mentioned under 'Structure' OR Three or five different explicit interactions that together cover every part mentioned under 'Structure' OR Four different implicit interactions that together cover every part mentioned under 'Structure'
Function	Input[1]	One Boundary System AND one interaction between Target System and Boundary System. The direction of the interaction is from Boundary System to Target System. Input and output systems can be the same.	One Boundary System AND multiple interactions between Target System and Boundary System. The direction of all the interactions is from Boundary System to Target System OR One non-Boundary System AND one interaction between Target System and non-Boundary System. The direction of the interaction is from non-Boundary System to Target System.
	Output[1]	One Boundary System AND one interaction between Target System and Boundary System. The direction of the interaction is from Target system to Boundary System. Input and output systems can be the same.	One Boundary System AND multiple interactions between Target System and Boundary System. The direction of all the interactions is from Target system to Boundary System OR One non-Boundary System AND one interaction between Target System and non-Boundary System. The direction of the interaction is from Target System to non-Boundary System.
Outcome	Stakeholders	One distinct group	One non-distinct group Multiple distinct groups

	Problem	One distinct problem/need/lack/demand of stakeholders	One non-distinct problem/need/lack/demand of stakeholders Multiple problems/needs/lacks/demands of stakeholders
	Benefit	One direct positive outcome affecting stakeholders, with or without a causal explanation.	Multiple direct positive outcomes affecting stakeholders, with/without a causal explanation. OR One indirect positive outcome affecting stakeholders, with or without a causal explanation.
	Detriment	One direct negative outcome affecting stakeholders, with or without a causal explanation.	Multiple direct negative outcomes affecting stakeholders, with/without a causal explanation. OR One indirect negative outcome affecting stakeholders, with or without a causal explanation.

[1] A boundary system (input or output) can be non-technological.

Table S2. Scoring instructions for Correctness.

SAFO aspect and element		2	1
Architecture	Structure	All parts are correct and precise	Half or more of parts are correct and precise, but not all
	Behavior	Ignore non-behavioral relations, if any are mentioned All behavioral interactions are correct and precise	Ignore non-behavioral relations, if any are mentioned Half or more of behavioral interactions are correct and precise, but not all
Function	Input	Input system/s (if mentioned) are correct and precise and Interaction/s of input system with system of interest (if mentioned) are correct and precise	Input system and/or interaction (whichever are mentioned) are correct but imprecise If multiple systems and/or interactions are mentioned: half or more of are correct and precise
	Output	Output system/s (if mentioned) are correct and precise and Interaction/s of output system with system of interest (if mentioned) are correct and precise	Input system and/or interaction (whichever are mentioned) are correct but imprecise If multiple systems and/or interactions are mentioned: half or more of are correct and precise
Outcome	Stakeholders	All groups are correct and precise	If multiple groups: half or more of groups are correct and precise, but not all If one group: correct but imprecise
	Problem	All problems are correct and precise	If multiple groups: half or more of problems are correct and precise, but not all If one problem: correct but imprecise
	Benefit	All benefits are correct and precise	If multiple benefits: half or more of benefits are correct and precise, but not all If one benefit: correct but imprecise
	Detriment	All detriments are correct and precise	If multiple detriments: half or more of detriments are correct and precise, but not all If one detriment: correct but imprecise