Framework for a Case Study Based Course in Safety and Mission Assurance in Human Spaceflight

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Problem Background

The majority of those who are exposed to safety-culture are those who work directly with safety or have witnessed a safety-concerning event. Decision-making in human spaceflight is heavily dependent on ethical behavior of designers and management. During major spaceflight incidents of the past such as the Challenger and Columbia Space Shuttle disasters, there was a noticeable gap in decision-making that resulted in tragedies, due to factors such as cost, time, and a desire for accomplishment. After these accidents, safety was taken more seriously in the industry than in academic settings. The concept of space safety is being taken lightly in the engineering education field. Exposure to safety practices are limited in current college curriculums. If humans are set to go to the Moon and Mars, safety-culture must be taught properly to fill the academic gap.

STS-107 crew members David M. Brown, left, Rick D. Husband, Laurel B. Clark, Kalpana Chawla, Michael P. Anderson, William C. "Willie" McCool, and Ilan Ramon.

Purpose

This research proposes a course framework to improve the strategies with which engineering courses are taught. It also encourages the use of case studies to promote autonomy, motivation, connection to the course material, and critical thinking for multiple-solution problem solving.

Hypothesis

If significant case studies of human spaceflight accidents, incidents, and close calls are used in the classroom to teach Safety and Mission Assurance (S&MA) concepts, students will emotionally connect to the event, making them aware of how integrity, ethics, and safety culture play a role in the engineering decision-making aspect of human spaceflight.

References

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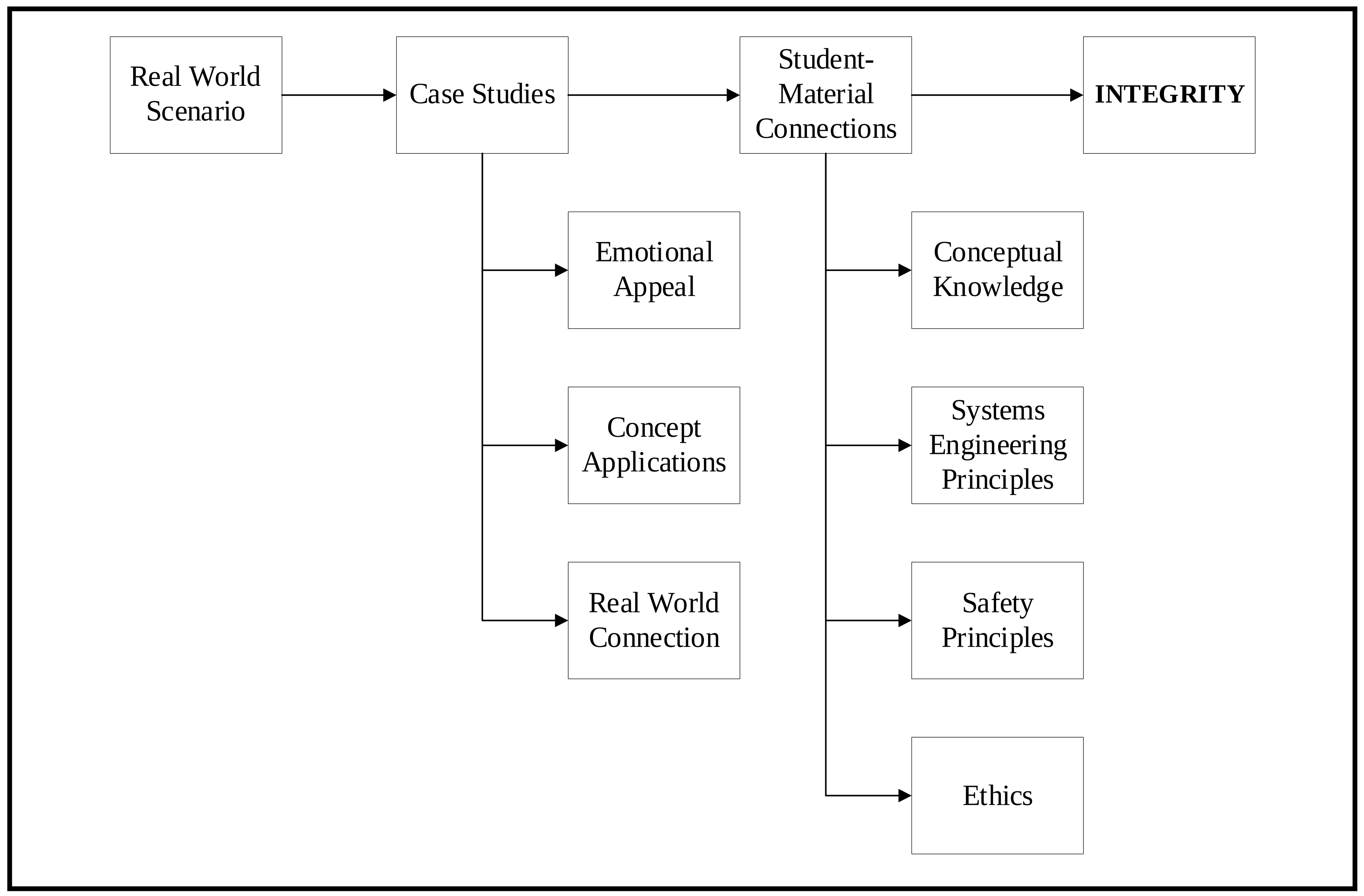

Flow diagram of how the introduction of case studies in courses leads to students with more integrity in the engineering workforce

Methodology

•Topics in systems engineering will be taught while reviewing significant accidents, incidents, and close calls in human spaceflight. Some of the topics are:
- Probabilistic Risk Assessments
- Risk Matrices
- Reliability
- Verification and Validation
- Common Cause/Mode
- Redundancy
- Fault Tolerance
- Hazard and Risk Analysis

•This is a systems engineering course designed to teach Safety and Mission Assurance for space systems, using an interdisciplinary approach with a macroscopic overview typical of systems engineering.

•The proposed method is a learner-centered approach, targeting student autonomy for problem solving in systems engineering. Autonomy allows the student to make choices in their problem-solving strategies. The element of choice and autonomy induces motivation, which is a key component of ethical decision-making.

•The proposed framework balances fundamental concepts of systems engineering with mild to moderate exposure to emotional information to address the logic and motivation that influence decision-making.

•The proposed framework also addresses retention for future applications, where lessons learned from previous events influence the outlook and approach a student takes in current and future events.

Discussion

•Learner-centered approaches address adaptability and **autonomy**. This allows individuals to learn on their own, applying critical thinking and problem-solving methods to case studies. The goal is for the student to apply the strategies learned in the classroom to real-world problems regardless of how it is presented.

•Autonomy allows students to have a **choice** in the strategies used to address problems instead of following predetermined sequential steps. This is ideal for rapidly-changing environments such as the space industry, where the fundamentals are constant, but the technology used rapidly increases in complexity.

•When the student is allowed to be in charge of the decision-making process, they feel more attached to the situation and the problem. This freedom produces **motivation** in the student to find a solution. One-solution linear problems, where students have no power over the outcome, imposes a lack of motivation to resolve the problem. Motivation is one of the three keys to the ethical decision-making process, along with personal values and logic.

•A major part of systems engineering is the concept of **trade-offs**. For example, performance of a vehicle may be traded for maintainability, where the system gets intentionally simplified. There are so many degrees of trade, that it falls under the multiple-solution umbrella, where solution-finding relies on critical thinking and higher-level problem solving. The idea is to deter from finding a "right answer" and aiming for understanding of the problem as a whole. If the student gets placed in a situation of uncertainty, they should nonetheless be able to find a solution.

Conclusion

•Students taking any systems safety course will be given the concepts they need to learn regardless of how the material is presented. With this framework, however, students will also be given the tools and motivations to have a sense of integrity, responsibility, and accountability when conducting S&MA work. These traits are vital for ensuring safe and ethical progress when sending humanity to the Moon and Mars.

•The authors recommend implementing a similar course structure in engineering programs in their respective institutions.

Future Work

•Further research into these concepts is being conducted.
•A course is currently in development using this framework.
•A Massive Online Open Course (MOOC) will be developed.
•Based on interest in and feedback from the MOOC, the course will be modified and implemented in a graduate-level systems engineering program.

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Mercury 1961-1963 | Gemini 1962-1966 | Apollo 1963-1972 | Skylab 1973-1974 | Shuttle 1981-2011 | ISS 1998-Present | Artemis 2022-Present | Lunar Gateway ~2028